Technical Report 1285

Virtual Environments for Soldier Training via Editable Demonstrations (VESTED)

Michael Szczepkowski, Thomas Santarelli, Kevin Stagl, Floyd Glenn, and John Paulus
CHI Systems, Incorporated

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While demonstrations are recognized as an effective tool to train key Army relevant skills, there is little detailed guidance on how to generate and present effective demonstrations. CHI Systems created a demonstration authoring tool, called the Virtual Environments for Soldier Training via Editable Demonstrations (VESTED), which guides an author through a demonstration creation process to select the specific learning goals to be demonstrated and to construct storyboards depicting the underlying behaviors, cognitive decisions and tasks being demonstrated. VESTED also aids the author in making the decisions about where and how to use the virtual environment (VE) medium and all of the other relevant authoring tools. The use of VESTED should reduce instructor workload and improve instructor efficiency by reducing the cost of developing demonstrations and permitting demonstrations to be executed on a wide-variety of affordable computer hardware.

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Virtual Environments for Soldier Training via Editable Demonstrations (VESTED)

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VIRTUAL ENVIRONMENTS FOR SOLDIER TRAINING VIA EDITABLE DEMONSTRATIONS (VESTED)

EXECUTIVE SUMMARY

Research Requirement:

Demonstrations are an effective and highly flexible training method and fulfill an essential role in military training. However, although they are recognized as an effective tool to train key Army-relevant capabilities, there is little detailed guidance on how to best generate and present effective demonstrations. Thus it is clear that construction of effective demonstrations for training Soldiers would benefit from more complete methodological guidance and technological support in order to improve the effectiveness and efficiency of military training. VESTED (Virtual Environments for Soldier Training via Editable Demonstrations) is a Phase II SBIR effort with the overarching goal of aiding the production of effective training demonstrations.

Procedure:

Year 1 of the effort focused on an extensive literature review examining the impact of demonstration design features on training effectiveness. Year 1 work also included the development of an instructional model concept. Additionally, we developed and articulated a comprehensive demonstration authoring use-model and system architecture. Finally, we constructed a virtual environment concept demonstration as an application case to inform the development of the system and authoring guidelines.

Year 2 of the effort focused on how to aid the author in developing detailed connections between demonstration training objectives and design features. A series of semi-structured interviews with videographers, documentary filmmakers, and multimedia specialists was conducted. We selected an additional application case to further focus our design efforts. Additionally, we examined the literature for approaches to both estimating training effectiveness and production costs. Finally, we designed and partially implemented the demonstration authoring tool.

Findings:

We began this effort with the expectation we would be developing a tool that would aid in the development of demonstrations through a process based on empirical guidelines. Demonstration authoring guidelines were developed, however with the understanding that some of the relevant research basis for this guidance may be ambiguous, changing over time and conflicting. Given these guidelines may not be as neat and generalizable as we would like; we concentrated on identifying the task requirements of the training demonstration author. VESTED was developed to aid in appropriately organizing their decisions and development tasks, all based on the fundamental assumption that understanding and specification of training objectives should guide

and thread through all aspects of demonstration design. VESTED functionality, as driven by the need to articulate design objectives, is fundamental to the achievement of effective demonstrations.

Utilization and Dissemination of Findings:

The use of VESTED should yield measurable instructor, training content, and trainee effects including those for instructional designers (e.g., positive instructor reactions, increased instructor motivation), with regard to content (e.g., increased quality of demonstrations), and for trainee performance (e.g., increased trainee motivation). The use of VESTED should reduce instructor workload and improve instructor efficiency by reducing the cost of developing demonstrations and permitting demonstrations to be executed on a wide-variety of affordable computer hardware systems. Moreover, by better matching instructional content to trainee' needs, VESTED provides a medium for enhancing trainee motivation, engagement and development by creating more meaningful learning experiences.

VIRTUAL ENVIRONMENTS FOR SOLDIER TRAINING VIA EDITABLE DEMONSTRATIONS (VESTED)

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VIRTUAL ENVIRONMENTS FOR SOLDIER TRAINING VIA EDITABLE DEMONSTRATIONS (VESTED)

This technical report describes the design and development activities completed through the end of Year 2 for the VESTED Phase II SBIR effort. The purpose of VESTED is to aid authors of demonstrations in: articulating the objectives, requirements, and constraints for a planned training demonstration; developing one or several storyboard 'cases' that would satisfy those conditions; and finally structuring the cost-benefit decision of selecting a preferred case and elaborating its specification into a detailed production plan.

As the U.S. military continues to redefine its role to include participation in low intensity conflicts, asymmetric warfare, and overseas contingency operations, it is necessary to continuously redefine tactical doctrine, and the training of that doctrine, based on lessons learned in the field. The provision of effective methods and technologies for training of military personnel has long been a major challenge to U.S. military forces, and recent activities in the Middle East have only escalated the stakes for broader ranges of training content, more reliable training results, and shorter training cycles for new recruits prior to overseas deployment.

The methods and processes known as Instructional Systems Design (ISD) have been developed over several decades to address military needs. In particular, the 11-volume MIL-HDBK-29612 addresses a broad range of training system design and development issues, including a nearly 300-page Volume 2A on ISD. For the broad category of Knowledge, Skills, and Attitude (KSA) competencies that must be trained, MIL-HDBK 29612 identifies the following sequence of instructional components as appropriate: (1) Introduction, (2) Essential or Core Information, (3) Examples or Demonstration, Practice and Feedback.

Demonstrations are an effective and highly flexible training method within the ISD framework. Unfortunately, however, although they are recognized as an effective tool to train key Army-relevant capabilities, there is little detailed guidance on how to best generate and present effective demonstrations. The complete guidance of MIL-HDBK 29612 (p. 140) is as follows:

Present demonstrations. Since procedures are always performed the same way on the job, only one example of how the procedure is applied is required. A demonstration is used as a concrete example of how a procedure should be performed and includes explanations of difficult steps. Procedures may be performed live by the instructor, on-line, downloadable, presented in audiovisual form, or appear in a workbook. Guidelines for developing adequate demonstrations are as follows:

a. Begin with a description of the specific situation in that the procedure will be demonstrated. Include all necessary tools and equipment.

b. Cover all steps in the order presented. Point out and explain common errors.

c. Indicate all steps requiring decisions and show the response for each decision. Although most procedures involve a set of steps, all of which are performed the same way every time, some procedures may require decision steps within the procedure. Draw the student's attention to these steps. This can be done by using the "if ..., then ..." format.

d. Exclude all nonessential information from the demonstration.

Thus, it is clear that construction of effective demonstrations for training Soldiers would benefit from more complete methodological guidance and technological support in order to improve the effectiveness and efficiency of military training.

The central objective of this Phase II SBIR effort is to produce an authoring tool and associated guidance to create effective demonstrations for Army training. We created a demonstration authoring tool, called the Virtual Environments for Soldier Training via Editable Demonstrations (VESTED), which guides an author through a demonstration creation process to select the specific learning goals to be demonstrated and to construct storyboards depicting the underlying behaviors, cognitive decisions and tasks being demonstrated. VESTED also aids the author in making the decisions about where and how to use the virtual environment (VE) medium and all of the other relevant authoring tools.

There are several compelling reasons for using VE representation instead of the alternative of using video recording of live actors and real physical environments to create demonstrations for Army training. The chief reason is that VEs can be much more easily controlled and edited than real environments (REs). This feature is especially important for the experimental research that is needed in order to develop more nuanced design guidance for demonstrations. Specifically, additional research is warranted to parse and model the effects of systematic manipulations of demonstration features (e.g., level of detail, perspective, representation of errors, lighting, highlighting, etc.) on instructor, trainee, and training content criteria. These kinds of systematically controlled variations of a broad range of demonstration characteristics can be accomplished more easily and cost-effectively in a well-designed VE authoring tool than in a real environment facility or studio. In fact, the effectiveness of this type of VE approach is documented (Lampton, McDonald, Rodriguez, Morris, & Parsons, 2001). Another key advantage of the VE authoring approach for demonstrations is that it offers the possibility of tighter integration with the use of VE approaches for facilitating the skill practice phase of training in the same instructional sequence, enabling a seamless transition from VE demonstrations in early phases of training to interactive VE exercises of the same skills in later phases. Other significant advantages of the VE approach derive from the considerable investments and advances in this area that both Department of Defense (DoD) and the commercial serious games area have made in the past decade, with powerful authoring tools and rich libraries of object imagery currently available at affordable and progressively decreasing costs.

VESTED has been developed specifically to facilitate the creation of demonstrations for training of diverse military skills, with no particular attention to whether or not the skills required interpersonal interaction. Although the intended focus was on the VE medium, it was clear from the outset that a major challenge for the training product author is to determine when

and how to use any and all of the available media in order to best achieve training objectives in a cost-effective fashion. Although we expect that VE will be optimal for many applications, it is also clear that the established media of video, still photography, and manual artwork will also be most appropriate for many cases depending on many factors. For the VE medium, in particular, it is clear that there are many existing and diverse software tools to aid the author in creation of products such as training videos.

The goal of VESTED is to provide the author with an organizing tool to aid them in making the decisions about where and how to use the VE medium and all of the relevant other authoring tools. The basic concept of VESTED is to offer a tool to aid the author in articulating the objectives, requirements, and constraints for a planned training demonstration, then to guide them through the development of one or several storyboard 'cases' that would satisfy those conditions, and finally to structure the cost-benefit decision of selecting a preferred case and elaborating its specification into a detailed production plan.

It is important to be clear about the definition and scope of the term *demonstration* as we use it in reference to VESTED. We define the common meaning of *demonstration* as:

An observable example of the performance of a task by one or more persons that is presented for the purpose of training the observer(s) to perform the task.

It will be useful to further explore the meaning of some of the elements of this definition. We most often think of demonstrations as visual depictions of task performance, though sound and especially verbal communications involved with the task can also be essential. In addition, it is critical and challenging to determine how to handle significant but inherently unobservable aspects of task performance, particularly cognitive and affective aspects that are not normally verbalized. These issues of visibility extend to the consideration of possible media for presentation of the demonstration, which include: (1) live performance by actors/role-players that are physically present at the demonstration site, (2) video recording of live actor performance, (3) video screen presentation of animated actors in a virtual environment, or (4) some hybrid combination of these elements.

There are many issues to consider surrounding the exemplar status of the demonstration. Is it a complete activity or just a part? Is it a dynamic representation of task performance or just a static snapshot? Does it show just one way to perform the task correctly or multiple acceptable alternatives? Is only correct performance exhibited, or are some typical errors in performance also included? Particularly significant is the issue of whether the example is just the *raw* performance of the task or whether it also includes additional instructional elements (e.g., tutorial presentation) that are provided to help the observer/trainee understand and learn efficiently from the demonstration. For example, in the case of a live demonstration, it is typical for an instructor to provide an instructional envelope around a demonstration, including focused comments about the performance example before, during, and immediately after the viewing of the demonstration. Training videos of demonstrations, both from live actors and animated virtual environments, generally provide a tutorial envelope around the raw performance example that may include an identification of the training objectives for the

demonstration, comments to draw attention to critical or difficult aspects of performance, and an explanation of unobservable cognitive activities.

Thus, to aid the production of effective training demonstrations during this program, we considered the following:

a. how to identify the appropriate scope for the role of the demonstration component within a complete training program in terms of what specific training objectives are to be used to establish the requirements for the demonstration;

b. what segments of task performance to represent in the demonstration;

c. whether to present just a single case of ideal performance or possibly multiple cases that may represent different ways of doing the task;

d. whether to present illustrations of common or dangerous errors in task performance and possibly how to avoid them;

e. whether to represent that performance using live acting, recordings of live acting, or animation in VEs;

f. how to select and use available relevant technology for animation and VE generation;

g. how to translate training objectives and other design decisions into script and storyboard for production;

h. what tutorial material and other production tools to use in order to provide a complete instructional envelope for the demonstration; and

i. how to factor the major constraining factors of cost and schedule into all the above decisions.

It is important that the VESTED tool is highly usable by the intended authors so that they can learn to use it quickly and they can generate demonstrations very quickly and efficiently. The design of the tool and the associated methodology integrated into the tool as embedded guidance and help must ensure that all generated demonstrations are highly effective in achieving their training goals. By better matching instructional content to trainees' developmental needs, VESTED provides a medium for enhancing trainee motivation, engagement, and development by creating more meaningful learning experiences. Thus, VESTED should have proximal effects on instructors, which translate into improved training content and, ultimately, more effective Soldiers.

VESTED Phase II SBIR Focus

The central objective of this Phase II SBIR effort is to produce an authoring tool and associated guidance to create effective demonstrations for Army training. The overall vision for the VESTED use model is articulated in the later section entitled "Vision for Overall VESTED Authoring Use Model." In summary, the envisioned VESTED functionality can be broken down into three sequential steps:

1. Demonstration specification step - where the author identifies the specific learning objectives to be modeled, reviews demonstration authoring guidelines, creates a set of demonstration storyboards that reflect the target behaviors, and then chooses a storyboard to fully implement.

2. Demonstration video generation step - whereby the demonstration author utilizes the specific game-based environment to instantiate the behaviors represented in the selected storyboard (thus generating a set of raw intermediate videos).

3. Video mixing step - in which the author imports intermediate videos into a commercial-off-the-shelf video mixing tool and performs post-processing to create the final demonstration video.

We began this effort with the expectation that we would develop a software tool that would support all the functionality outlined above. Our initial undertaking was to develop the demonstration authoring guidelines, however, with the understanding that some of the relevant research basis for this guidance may be absent, ambiguous, changing over time, and/or conflicting. Upon concluding that these guidelines were not as mature and complete as we desired for the VESTED concept, we determined to include only a few general guidelines in the initial version of VESTED and to plan for expansion and revision of those guidelines based on new research results and the experiences and evaluation results of early VESTED applications. For VESTED software design, we concentrated on identifying the task requirements of the training demonstration author and developed VESTED to aid in appropriately organizing their decisions and development tasks, all based on the fundamental assumption that understanding and specification of training objectives should guide and thread through all aspects of demonstration design. VESTED functionality, as driven by the need to articulate design objectives, is fundamental to the achievement of effective demonstrations. Steps 2 and 3 above represent areas where new custom VESTED software would add value to the overall VESTED tool; however, it was found feasible to accomplish those steps according to VESTED procedures using commercially available software tools.

Consequently, during this effort, VESTED was developed to offer a tool that aids the author in articulating the learning objectives, requirements, and constraints for a planned training demonstration, then to guide them through the development of one or several storyboard 'cases' that would satisfy those conditions, and finally to structure the cost-benefit decision of selecting a preferred case and elaborating its specification into a detailed production plan. Thus, the current VESTED tool concept and software products

address Step 1 of the above VESTED vision and the output of that step includes some detailed guidance for Steps 2 and 3 for which future extensions of VESTED are intended.

Process for Guideline Development

This section details our approach to develop demonstration authoring guidelines. The first step is to describe a review of the impact of demonstration design features on training effectiveness as referenced in the literature. We then present our work on developing a VESTED instructional model concept. Next, is a discussion of the formation of an analytic framework, the purpose of which is to establish a reference for the specification of design guidelines for training demonstrations. This is followed by a presentation of our plan and findings distilled from a series of semi-structured and unstructured interviews with videographers, documentary filmmakers, and multimedia specialists which were executed to better understand the process and key considerations inherent in developing demonstrations. Finally, we present our initial collection of instructional design guidelines synthesized from our review of the literature and our work on the analytical framework.

Literature Review

A literature search was conducted using online and library resources, starting with publications identified in the Phase I research and the Phase II proposal, and including the network of citations triggered by the initial tier of publications. Electronic searches of computerized databases using multiple combinations of relevant key words were executed. More specifically, scholarly-oriented search engines (e.g., Google Scholar©), meta-databases (e.g., EBSCOhost), abstracting services (e.g., Dissertation Abstracts International), lessons learned repositories (e.g., Defense Technical Information Center) and electronic proceedings (e.g., Proceedings from the Interservice/Industry Training Systems and Education Conference (I/ITSEC)) were tapped as sources of valuable information on demonstrations. The second step of the literature review process involved a more targeted search of specific academic journals known for consistently publishing top-tier training research (e.g., Journal of Applied Psychology, Personnel Psychology, Military Psychology, Organization Development Journal, Academy of Management Journal, Small Group Research, and Human Factors). The third step of the literature review involved ancestry back-tracing whereby the bibliographies and references of already identified studies were searched to locate earlier, seminal work in this area. The fourth and final phase of the four-step literature review process involved reaching out to our vast network of colleagues representing multiple scientific disciplines to secure unpublished articles, technical reports and conference manuscripts.

A total of eighty-five papers of significant interest were identified via the literature review; abstracts and citations were obtained for all of them, and full copies for about half. Each paper was then classified via taxonomic research using several taxonomies (e.g., research type) and associated taxons (e.g., survey vs. experimental) relevant to the VESTED project. A decision rule was established whereby each study

was classified into a single taxon by its overall taxon match. The following considerations underpinned the taxonomic effort:

- Application area requirements and product evaluation
- Cost analysis
- Dramatic arts
- Developmental processes (i.e., maturation, especially in adolescence)
- Guidelines for demonstrations
- Industry/government panel reports
- Neurophysiology
- Parametric experimental studies
- Survey
- Scenario Generation
- Sleep effects on learning
- Sports science
- Storyboarding
- Theory
- VE technology

Two of the categories–parametric studies and theory–were found to be quite broad and were accordingly each broken down into several sub-categories. For parametric studies, the subcategories included:

- Errors
- General evaluation of demos
- Modality
- Observation vs. practice
- Perspective
- Sequence and repetition
- Timing

For publications on theory, the subcategories included:

- AI learning theory and applications
- Behavior Modeling Training (BMT)
- Cognitive
- Cognitive load theory
- General
- ISD in general
- Procedural learning

Publications are listed in Appendix A and organized according to the above-described classification. Not surprisingly, the results of this search were extensive and diverse, touching on all of these disparate issues and aspects of training demonstrations. However, we were able to identify a small group of clusters of research that are especially noteworthy. These are briefly discussed in the following paragraphs.

The U.S. Army Research Institute (ARI) has conducted several investigations to address the training effects of demonstrations. A study by Shlechter and Anthony (1996) provided an extensive exploration of the general problem of training value of demonstrations and evaluated the training value of a set of training demonstration videos produced by the Army for a new experimental command and control system. The authors point out that explanations in demonstration tapes should be spoken rather than presented as written text because of cognitive load effects on visual processing of demonstration visuals; demonstrations should be presented several times to achieve maximum effect; and "cognitive modeling" (model narration of thought processes) should be provided to explain cognitive activity accompanying observable actions. The authors found the specific demonstration videos evaluated to be valuable for enhancing training in combination with practice. A series of earlier ARI studies by Hagman (1980a, b, c) are summarized below under the category of motor learning.

Behavioral Modeling Training (BMT). The area of work referred to as (BMT) is derived primarily from the social cognitive theory of Bandura (1977). This theory focuses on the central importance of observational learning processes in many areas of learning and behavior modification, both intentional and unintentional. Key aspects of the observational learning processes are attention, retention, production, and motivation. The majority of this work employs live actors as the modelers of the target behaviors, with much of the research and applications set in the context of management training. Much of this work is relevant to key issues identified for VESTED. Mayer and Russell (1987) review the issues of variability in model behavior and types of verbal explanations (termed “learning points” in BMT). Baldwin (1992) notes specifically that there may be an inverse relationship between reproduction and generalization in BMT with non-variable model behaviors facilitating reproduction of those precise behaviors by the trainee but yielding little generalized learning while more variable model behaviors may lead to slower learning of the ability to reproduce the target behaviors but much more effective learning of generalization. Taylor, Russ-Eft, and Chan (2005) provide a meta-analytic summary of work in the overall BMT area.

Experiment-based cognitive research. Over the past decade, a group of researchers have conducted systematic theoretical developments and experimental investigations of diverse aspects of training demonstrations and other aspects of training pedagogy as implemented using the various media and tools of electronic and virtual applications, such as simulation, computer games, and virtual environments. The concept of cognitive load limitations as key factors in training has been advanced by a number of researchers (Chandler & Sweller, 1991; Mayer & Moreno, 2003; Paas, Tuovinen, Tabbers, & van Gerven, 2003). Wouters, Paas, & van Merriënboer (2008) developed guidelines for observational learning applications based on cognitive load theory, with

recommendations in the three areas of managing subject matter complexity, eliminating obstructions to learning, and stimulating trainees to focus on active processing of relevant information. In a related publication (Wouters, Paas, & van Merriënboer, 2009), they observe that spoken explanations are superior to written explanations in accompanying animations only when there is no encouragement or opportunity to focus on and process the explanations, while text explanations can be superior when trainees are given direction and opportunity to reflect on the explanations.

Sports science and motor behavior. Possibly the largest body of work on the subject of observational learning has occurred in the areas of motor behavior, especially with applications to various sports. Ashford, Bennet, and Davids (2006) offer a wide-ranging meta-analytic review of much of this literature, focusing on the relative effect sizes for criteria in the areas of movement dynamics and movement outcomes. A series of studies by Hagman (1980a, b, c) considered the training effectiveness of demonstration presentations of a simple psychomotor task, examining the effects of variations in the sequence of demonstration and practice events relative to acquisition speed and subsequent recall/decay. Results indicated that repeated presentation with little practice produced much poorer retention than minimal presentation and much practice, and that alternating presentation and practice was best for errors in acquisition and short-term retention but was intermediate between mostly practice (best) and mostly presentation (worst) for longer-term retention. Although studies in this area have addressed diverse aspects of motor behaviors and types of individual and group sports, one fairly consistent and basic message seems to be that demonstration combined with visual and verbal cues produces better performance than practice only or any component cue alone (e.g., Janelle, Champenoy, Coombes, & Mousseau, 2003).

Neurophysiology. Recent neurophysiological research has revealed the existence of brain structures that seem to be specifically adapted for the performance of observational learning, enabling the individual to understand observation of the behaviors of other individuals in terms of the individual's own behavioral capabilities. Petrosini, Graziano, Mandolesi, Neri, Molinari and Leggio (2003) report that the cerebellum is critical for the acquisition of complex behaviors by observation, but is not so much involved in fluent performance thereafter. Frey and Gerry (2006) describe a mirror system (inferior frontal and parietal cortices) which shows increased activity during observation of a model and greater activity when the observer intends to replicate the model's action, with activity in the intraparietal sulcus especially critical. Rizzolatti, Fogassi, and Gallese (2006) identify specific "mirror neurons" in the premotor cortex of monkeys that are specifically activated during imitative behaviors and note that functional Magnetic Resonance Imaging (fMRI) results indicate similar activation in correlating human brain regions for human imitative behaviors. In a more speculative vein, Ramachandran and Oberman (2006) suggest the possibility that dysfunction in these mirror-neuron structures could be a partial cause of some forms of autism by producing failures in the capability to understand the behaviors of others and relate them to one's own behaviors.

Dramatic arts. There are several noteworthy recent publications by one researcher that concern the applications of principles and techniques in the dramatic arts for enhancing the engagement and training effectiveness of educational games and other instructional products (El-Nasr, 2004, 2005, 2007). Hopefully, this type of work will be expanded in the near future to provide guidance for all of the aspects of training demonstrations that are understood to influence the success of the training experience but do not seem to lend themselves to systematic experimental study (e.g., lighting, transitions, perspective shifting, background music, etc.).

This brief summary of several key areas of research literature pertaining to the design of training demonstrations has led us to the conclusions that there is a very large body of relevant work reflecting diverse directions of inquiry, and much significant new work should be expected in the near future, especially in dynamic new areas such as the connections of cognitive experimentation and neurophysiology via techniques like fMRI. However, it has also become apparent that many detailed issues regarding the effectiveness of specific demonstration design features seem to be dependent on factors such as task type, learning criteria, and other features of context. The issue of whether and how to represent common errors has been of particular concern in this regard. Shlechter & Anthony (1996) recommended that models should be shown making mistakes but also indicated that the research literature was inconclusive on this point. For example, on a medical hand-washing task, Riolo (1997) found no differences in the training effectiveness of demonstrations with or without errors. Of course, failure to find an expected effect could be the result of either an insensitive experimental procedure or the absence of a real effect (or both). Still, in many applications to more complex skills, it is typical to provide modeling of common errors and even to evaluate alternative techniques to insure that the trainee recognizes the displayed erroneous behaviors (e.g., Jentsch, Bowers & Salas, 2001). The lesson for a design tool like VESTED seems to be to provide a mechanism for offering design guidance to an author of a training demonstration with the understanding that some of the relevant research basis for that guidance may be ambiguous, changing over time, and even with individual studies conflicting with one another in some cases, thus requiring the user to resolve the appropriate interpretations of the emerging research picture for each application context while awaiting more complete consensus guidance.

Instructional Framework Concept

Training is a planned activity executed to specifically target a trainee's or collective's latent capacities and capabilities as well as observable performance processes for development. In order for investments in training technologies (VESTED) to translate in to organizationally valued outcomes (increased use of safe practices), a chain of effects must unfold over time; preferably in accordance with a well-conceived theory. To more fully illuminate the anticipated effects and benefits of the VESTED solution, we formalized our theory of VESTED's effects by leveraging the science of training to specify: (1) what effects are expected from the system, (2) how the effects are related in a coherent network of causal relations over time, and (3) the conditions under which the effects are and are not interrelated (see Figure 1).

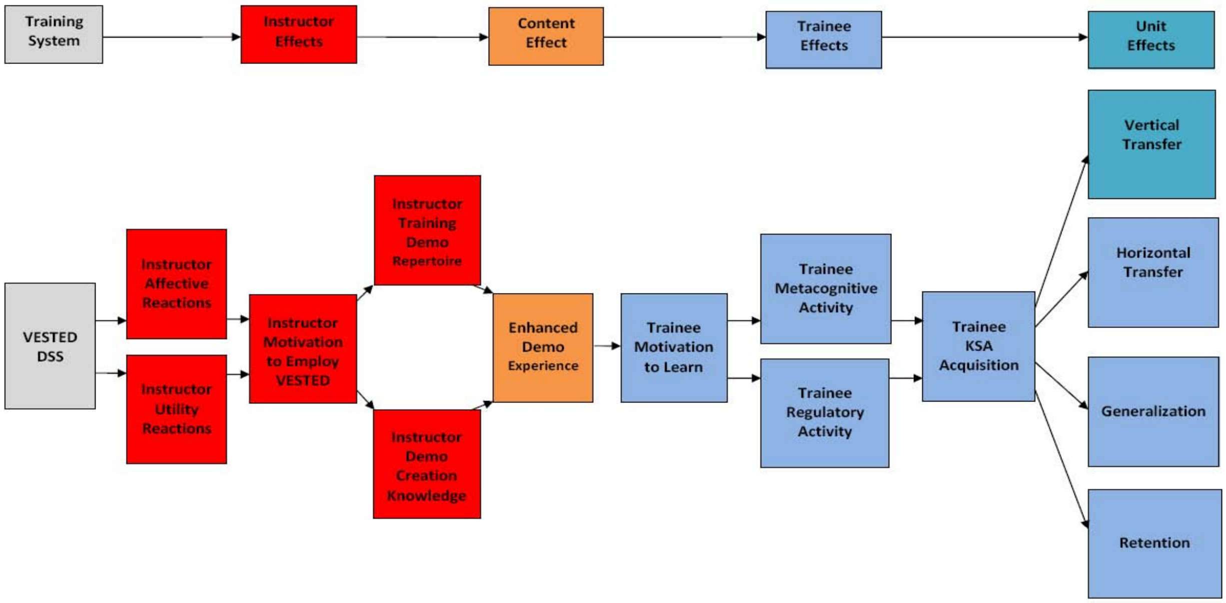


Figure 1. VESTED effects framework.

As is illustrated in Figure 1, it is anticipated that those units institutionalizing VESTED will set in motion measurable changes in instructors' knowledge, skill, and attitude (KSA) and thereby trainees' KSAs; as mediated by enhanced demonstration content. Moreover, over time, the introduction of VESTED should enhance performance transfer from the training context to the field and ultimately to positively affect the larger collectives (crews, squads, platoons) of which trainees are members.

By articulating a substantive theory of the treatment (VESTED), and detailing its expected relationships with mediating processes and proximal and distal outcomes, we have clearly stated the anticipated benefits of VESTED, as well as mapped the experiment-based multivariate research required to substantiate these assertions.

In addition to fostering common ground on VESTED's potential benefits, and shedding light on how to determine whether the articulated benefits accrue via systematic research efforts, Figure 1 also provides insight about how VESTED functions, what features to modify should it yield less than optimal results, and how to encode, communicate and capitalize on the formative and summative findings yielded via training effectiveness evaluations of VESTED.

The Evolution of Expertise

The central goal of training is generally envisioned as transforming the actual trainee into the ideal trainee where ideal is defined by targeted competency and/or performance levels as established by instructors or other training subject matter experts (SMEs). Thus, both the actual

and ideal trainees can be represented as KSA and performance models, delineating the latent knowledge, skill, and affective competencies, as well as the manifest taskwork and teamwork performance processes that enable, drive, and culminate in performance outcomes often ultimately evaluated in terms of their effectiveness by key stakeholders. Training then consists of the various manipulations that are contrived to effect the desired transformation in latent capacities and capabilities as well as manifest performance processes, typically consisting of some combination of tutorial, demonstration, interactive/experiential exercise, evaluation, and feedback components. Training of most complex skills is expected to employ components in all of these areas, sequenced and repeated to iteratively achieve desired effects.

An idealized method for optimal training is to develop detailed characterizations of the actual student model and desired student model, to then derive the differences between the two models that constitute the changes that must be effected, and then to select and apply the most appropriate training manipulations to produce those changes. The basic process representation envisioned here is illustrated in Figure 2, which presents the concepts of the Actual Student Model (ASM) and the Ideal Student Model (ISM) as the foundational elements of this view of training, with each delineating representations of each of the various aspects of declarative knowledge, procedural knowledge, and perceptual and motor skills. The Difference Student Model (DSM) represents the assessed component differences between the ASM and ISM, differences that are to be reduced or eliminated through the training process.

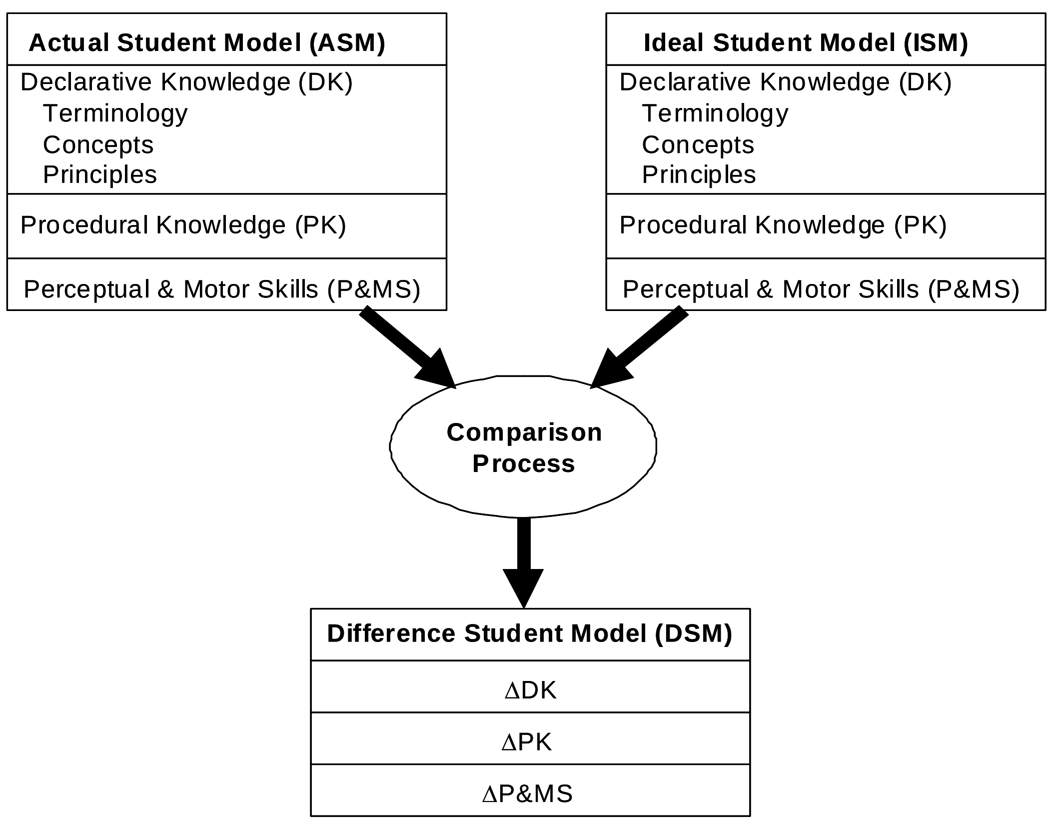


Figure 2. Concepts of actual, ideal, and difference student models.

We envision the KSA map of the trainee to represent a complex network of declarative knowledge, procedural knowledge, perceptual-motor skills and problem-solving skills that are relevant to the performance of the tasks being addressed. We can then compare the KSA map of the actual student with that of the ideal student in each of these component areas and determine the differences that need to be addressed. Additional detail about the KSA constellation comprising the ISM is provided next.

Trainee-Centered Training

The positive and negative models depicted in VESTED-based demonstrations, as well as the narrative descriptions they encompass, are advanced as levers instructors can use to close gaps between the ASM and ISM. This process may be best illustrated by an example from Military Operations on Urban Terrain (MOUT); the first use-case of VESTED selected by the research team. When considering the MOUT domain, the visual demonstration of the correct procedure (i.e., positive model) for short-stocking an M-16 rifle via VESTED should enhance trainee learning of MOUT tactics, techniques, and procedures (TTPs). Figure 3 depicts the role of repeating, varying, and cognitively rehearsing demonstrations of short-stocking in affecting a trainee's motivation to learn MOUT TTPs. We suggest that highly motivated trainees are more likely to allocate their attention and self-regulatory resources to learning than their relatively less motivated teammates.

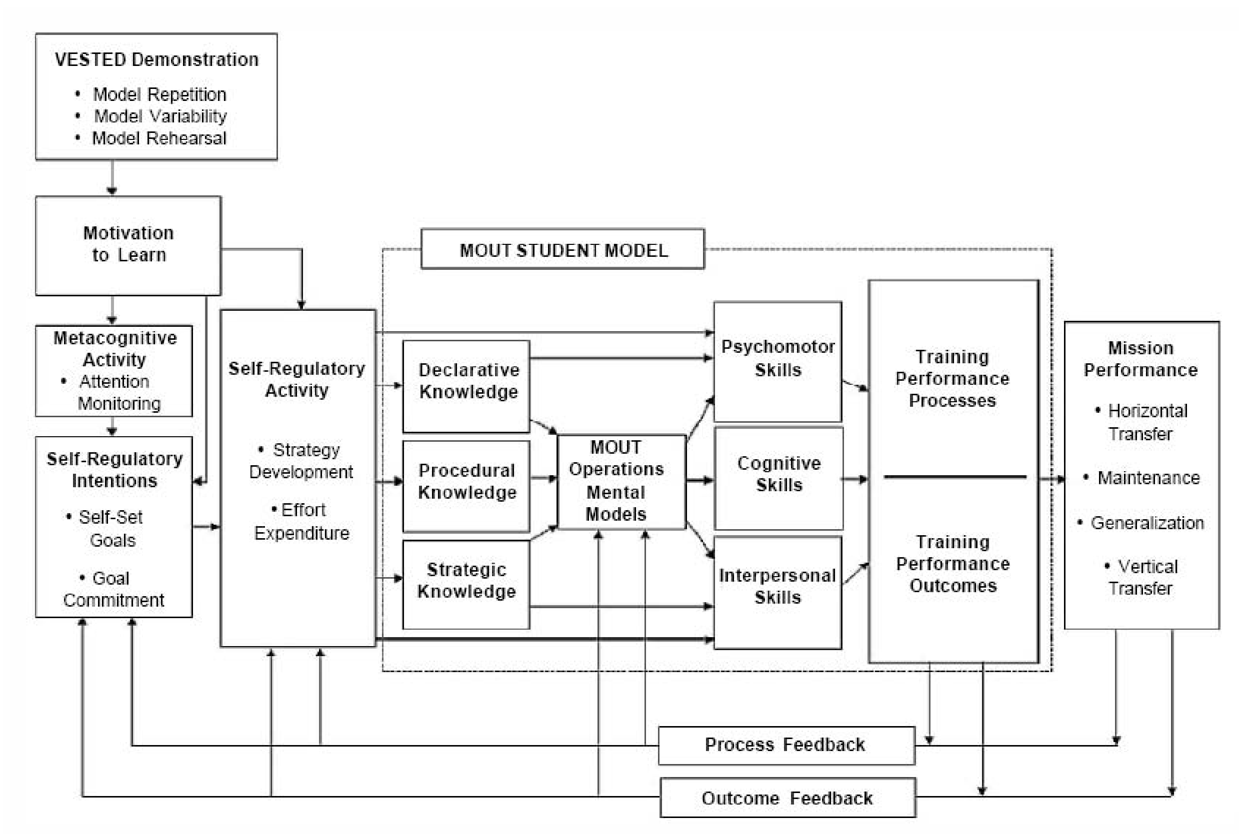


Figure 3. VESTED MOUT demonstration student effects model.

The establishment of goals, and the expense of effort in goal pursuit, enables the process of learning by which trainees acquire MOUT expertise. Figure 3 depicts our conceptualization of MOUT expertise in terms of the MOUT ISM (as illustrated in the dotted line box). We suggest trainees subjected to demonstrations who are motivated, attentive, and actively engaged in the learning process will be better positioned to acquire the knowledge, mental models and skills required to effectively enact the performance processes (e.g., communication, coordination, collaboration) that underpin successful urban operations. Over time, properly executed performance processes will culminate in training outcomes (targets acquired, obstacles safely navigated, etc.) that are more objective indicators of learning. The capacities and capabilities reaped from exposure to VESTED demonstrations should ultimately transfer to mission operations, enhancing a given trainee's performance and also that of his/her team, squad, platoon, company, and battalion as illustrated by vertical transfer in Figures 1 and 3.

Development of an Analytic Framework to Structure Design Guidance

This section addresses the requirement to create an analytic framework that will allow us to interconnect specifications of training objectives, trainee characteristics, and training program characteristics as a foundation for the formulation of training design guidelines for training demonstrations and, more generally, for complete training programs. We have identified the following taxonomies as relevant for each of these task, trainee and training program characteristic component areas:

- Task Characteristics
  - *Modality*
    - <u>Cognitive</u>
    - <u>Motor</u>
    - <u>Perceptual</u>
      - Visual
      - Auditory
      - Verbal
  - *Complexity*
    - <u>Unordered or weakly ordered steps or actions</u>
    - <u>Simple linear order</u>
    - <u>Re quiring branching</u>
      - Amount of branching required
      - Conditions for branching
        - *Perception*
        - *Communication*
        - *Judgment (decision, complex cognitive determination)*
  - *Agent numbers*
    - <u>Performer</u>
      - Single agent (solitary individual performer)
      - Multiple cooperating agents (teamwork situation)
    - <u>Non-cooperating contextual agents</u>

None
Single other agent
Multiple other agents

Flexibility

Rigid (task must be performed precisely as specified)
Variability is tolerated but not necessary
Variability is required in order to adapt to varying conditions of context

Scaffolding on other KSA

Prerequisite KSA (from selection or prior training)
Integral component KSA

Motor skills
Perceptual skills
Cognitive skills

Terminology
Concepts

Performance criteria

Retention
Automaticity
Transferability
Timing
Verbalizability

Trainee Characteristics

Prior relevant knowledge and skills in all relevant areas and criteria

None
Some, mainly correct
Some, mainly incorrect and counterproductive

Relevant cultural background/context (Hofstede dimensions)

Power distance index (deference to organizational hierarchy)
Individualism vs. collectivism
Masculinity vs. femininity
Uncertainty avoidance index
Long-term orientation

Specific error tendencies that should be countered through training

None
Some, mostly the same across trainees
Some, highly variable across trainees

Individual characteristics vs. population distribution statistics

Since we must assume that this framework will require us to separately examine each cell in the intersection of all of the orthogonal categories, the total number of cells to be considered is clearly very large. However, it is clear that not all of these cells deserve equal attention. In addition, we should be able to greatly simplify the multiplicative explosion of cells in the

framework by identifying many cases where there are good reasons to assume that interactions between categories are likely to be negligible or otherwise uninteresting. Indeed, it seems unlikely that we should need to consider interactions between most of the trainee characteristics categories and any of the other category dimensions. The main exceptions in this area would seem to be considerations of how tendencies to make errors should be considered relative to demonstrations of errors and possibly how some other demonstration features might interact with the novice-expert dimension of trainee experience.

The purpose of the proposed framework is to establish a reference for the specification of design guidelines for training demonstrations. To a large degree, we expect that the formulation of the design guidelines will occur almost as a collateral aspect of the identification of the framework cells. Essentially, the cells are defined as the combinations of categories for training objective, trainee characteristics, and demonstration design features for which a single design guideline (or coordinated set of guidelines) can be formulated. By revisiting the results of our earlier literature review, we identified both the conditions that are appropriate for the definition of framework cells and the guidelines that are warranted for those cells. The literature concerning Army applications also provided indications of relative priorities for the need for guidelines in many of the areas where existing research literature is missing or ambivalent. The scale of the required effort in this regard is determined much more by the number of design features of interest (on the order of a dozen) and of publications that must be re-examined (on the order of 100), with only a few publications that are pertinent to each design feature, rather than the number of potential cells in the framework (in the tens of thousands), so it should be understood to be a practically feasible undertaking.

Videographer Interview Process & Qualitative Analysis

A series of structured and unstructured interviews were conducted with subject matter experts (SME) videographers and multimedia specialists including a: (1) Director and Producer, (2) Director, (3) Associate Director, (4) Director of Post Production, and (5) Associate Producer. All but one of the five interviewees also serves as an Instructor at an institution of advanced learning. The interviews were executed to better understand the processes and key considerations inherent to scoping, storyboarding, and developing documentary films, training and informational videos, commercials, and multimedia content. The purpose of this process was to delineate insight about functions and features that would enhance the VESTED software application. In addition to informing the VESTED design process, interviewee feedback also served to further confirm several of the ideas originally generated by members of the VESTED integrated project team; as well as to illuminate insight about possible downstream functionality.

The Critical Decision Method (CDM), grounded in a multiple-pass event retrospection process, was chosen as the approach of choice to guide the first round of semi-structured interviews. CDM extends the critical incident interview technique by including opportunistic questions that elicit aspects of expertise, such as the basis for making perceptual discriminations, conceptual discriminations, judgments, and decisions in a contextually rich cue stream (Hoffman, Crandall, and Shadbolt, 1998; Klein, Calderwood, and MacGregor, 1989). CDM yields situation records, timelines, and descriptions of decision requirements. The effectiveness

of this approach has been demonstrated in several domains and thus it was selected to elicit information about the video scoping, design, and production process.

The CDM approach began as an interviewee selected a set of project cases that broadly defined the parameters of the subsequent discussion. Next, a participant was asked to isolate the critical incidents in a particular project case that they felt defined expertise. A participant recount of the incident was elicited, with equal emphasis on the incident as well as on its antecedents and outcomes. During the CDM-based dialogue, the interviewer diagramed a timeline of events and the basic stage-specific incident information (e.g., stakeholders, facts, resources, etc.). The mapped timeline was then shared with the interviewee for verification and/or revision. After common ground was established about the people, systems, and data in play in a project, the CDM process proceeded via progressive deepening to further distill lessons learned that would inform VESTED's functionality.

The second round of interviews was anchored in a scenario-based process. Interviewees were asked to participate by role-playing a character that owned a video production studio in a single video production scenario that consisted of four interrelated sub-events. The four events presented conditions, issues and core challenges that spanned project scoping to project completion during a fictitious but realistic video production project with multiple stakeholders. A total of three scenario-based interviews were conducted.

The third round of interviews was characterized by an open, unstructured dialogue with two SMEs with extensive expertise in storyboarding and animated storyboarding. The conversations which ensued were centered on the strengths and limitations of five commercially available and widely-used storyboarding tools (e.g., Celtx, Final Draft, FrameForge, Hollywood Screenwriter, Toon BOOM).

The fourth-, and final-round, of interviews involved presenting screenshots of the present implementation of VESTED to three SMEs in order to gather feedback about anticipated tool content and functionality; as well as about the proper placement and sequencing of VESTED's features. SME's affective, utility and difficulty reactions to VESTED were also operationalized.

In order to better inform the VESTED design process, the insight generated during each phase of the interview process about video project scoping, planning and production was mined, vetted in meetings by the research team, and where appropriate, leveraged to enhance VESTED functionality. For example, several SMEs lamented the lack of actionable advice about how to accurately estimate the total costs associated with planning, executing and delivering a multimedia project to their clients. Although it was the original intent of the research team to address cost and benefit issues via VESTED's features, the expert feedback from these potential end-users ultimately served to increase our confidence that this was indeed a worthwhile pursuit amongst the many competing functionality options for limited project resources.

Design guidance gathered from the SME interviewees that could not be fully incorporated into the current version of VESTED was assembled into a master list of features appearing below. SME interviewees suggested a wide-range of controls, features and functions that would potentially further enhance the usability and effectiveness of VESTED, including: (1)

pre-production cost-benefit and inventory tracking tools, (2) drawing tools, (3) editing tools, (4) production tools, (5) tools for creating animatics, and (6) pipeline integration tools. The features and functionality culled from the interview process which were deemed most pertinent to improving VESTED's design in the future are listed below.

- Auto-populating Timeline
- Complete Project Timeline View
- Project Time Calculator
- Equipment Tracking Tool
- Production Tracking Form
- Shot List Tool
- Shooting Schedule Form
- Pre-visualization of Photo Accurate Set
- Multi-camera Control Room Interface
- Object Importing and Authoring
- Object Relationship Assistance
- Character Expression Manipulation
- Correlated Film Media and Aspect Ratio
- Correlated Film Size and Aperture
- Editable Set Parameters
- Embedded Room Building Assistance
- Snap Construction of Objects and Environments
- Object to Object Smoothing
- Keyword-based Search of Object Libraries
- First-person and Overhead Diagramming
- First-person and Overhead Blueprinting
- Camera, Crane and Boom Manipulation
- Camera Meta-data Tagging and Printing
- Pixel or Multi-layer Vector Manipulation
- Flip Book and Onion Skinning
- Definable Panel and Layer Attributes
- Auto-generated Storyboards from Images
- Real-time Storyboard Preview
- Script Creation and Importing
- Auto-conversion of Scripts to Comply with Standards
- Import of Soundtracks and Volume Editing
- Export of Storyboards in .mov and .swf Formats
- Export of Storyboards to Photoshop via .psd Files

In addition to the SME dialogues described above, interviewees' reactions to the VESTED tool, given the envisioned condition that it was fully instantiated in working software

application form, were also captured during the fourth- and final-round of interviews. SME's affective, utility and difficulty reactions to VESTED were operationalized via a verbal administration of three standardized reactions measures. The findings of this process provided quantitative evidence for the theorized proximal mediating variables (viz., positive instructor affective and utility reactions) of the effects attributable to VESTED, as depicted in Figure 1.

Interviewee/instructor respondents reported favorable affective reactions (16 out of a possible 21) and utility reactions (16 out of a possible 21) to VESTED. These findings, while very preliminary, suggest that interviewees/instructors perceived that VESTED would be both enjoyable to use, and effective for creating demonstrations for training, should it ultimately be fully implemented in software form. Of note, respondents also reported that, sans a robust embedded help menu system, VESTED may be somewhat difficult to learn to use and apply to create demonstrations for training (9 out of a possible 14 in terms of difficulty reactions). Collectively, these findings suggest VESTED would be well received by end-users as well as valuable as a decision support tool during the demonstration specification and design process. The findings also suggest that additional embedded guidance and support is warranted in order to ensure VESTED users can maximize the value of this tool in support of their training efforts.

Formulation of Guidelines for Demonstrations

Why Not To Demonstrate

Before beginning to formulate guidelines for constructing training demonstrations, it is important to consider the prerequisite questions of whether any implementation or use of (new) training demonstrations are needed or warranted in the application domain of interest. Demonstrations are not necessarily always used in training for a variety of reasons, sometimes justifiably and maybe sometimes not. A Wall Street Journal article (Pasztor, 2009) describes a National Transportation Safety Board's investigation of an airliner crash in which lack of demonstration of a key procedure may have been implicated as a cause. Accordingly, in addition to addressing the positive reasons why a demonstration may be warranted in a training program using an objective-driven design approach, it is useful also to consider the reasons why demonstrations may be rejected. Some of the principal reasons for rejection are:

- Production of a demonstration that would be good enough to be beneficial would be too costly (in terms of financial budget, time, human resources, etc.).
- Production of a demonstration would be too dangerous (e.g., for showing how to recover from crisis situations).
- A demonstration would focus the trainee on a single case or a very small number of cases rather than the development of general abilities that can readily be adapted to diverse conditions; therefore, a focus on individual cases will tend to take the focus away from the needed abstraction and generalization.
- The task is performed very differently by different experts or in slightly different conditions so it may be misleading to demonstrate just one or a few of these examples.
- The relevant behaviors are primarily cognitive and, therefore, cannot normally be visualized–there is little or nothing that is normally observable in the target behaviors.

- The existing training program has always worked just fine without any demonstrations so there is no reason to add any now.
- It is very difficult to see and understand the subtle behaviors that are critical to successful performance and it is likely that trainees would be distracted by the many more salient but irrelevant aspects of behavior.
- Demonstrations are viewed passively by trainees whereas active engagement in the training process is critical for successful training–some or many trainees may not pay close attention or learn very effectively from passive observation of a demonstration.

It is crucial for the design process to address all of these concerns to the degree that they are applicable. Still, we assume that, in general, the instructional developer will want to at least explore the possibility of producing a new or improved demonstration in order to benefit a training program.

Key Questions to Drive Design Guidance and Initial Guidance

The basic idea for VESTED design guidance is to assist the user in specifying the objectives of the training program (thus addressing the scope of the total training program, not just the demonstration) and then in elaborating on those objectives to the point where general heuristic rules (that we develop as much as possible from archival research publications) can be used to generate suggestions and specifications for scripts for training components, specifically for training demonstrations.

Demonstration design guidance can be structured in the form of a process flow diagram consisting of a network of questions with branching to general and detailed recommendation nodes determined according to the answers to the questions. The questions are concerned with the various relevant aspects of training objectives, target task characteristics, and target trainee population characteristics. Following are some of the key questions for this process flow followed by some initial suggestions for guidance that would be provided for each of the possible answers to the questions:

a. To what degree is the focal task comprised of potentially observable physical action versus unobservable cognitive activity?

(1) All observable physical action–Plan on standard video demonstration of complete task.

(2) Partly physical action and partly cognitive–Plan on video demonstrations of observable task components with verbal explanations and/or cognitive modeling (i.e., “thinking aloud”) to represent cognitive aspects.

(3) All cognitive–Plan on primarily verbal explanation of task augmented with visual and auditory illustrations of key principles if possible.

b. Is the observable physical action (especially the most challenging aspects to be learned) primarily dynamic movement or static posture?

(1) Dynamic movement–Plan on standard video demonstration focusing especially on the most difficult aspects of the required movements, such as by zooming in, slowing down, etc.

(2) Static postures–Plan on video demonstration of postures, using techniques such as panning and highlighting to draw attention to the most difficult aspects of the postures and also providing clear illustration of how the postures are sequenced and transitioned along with any associated required movements.

c. Are <some/many/all> of the key aspects of task performance typically observable from <one/multiple> visual vantage points?

(1) Yes–Plan on standard video demonstration of complete task as viewed from appropriate perspectives. Also, plan to employ key perspectives that have special importance, such as the perspective of the adversary, perspectives that reveal special risks/vulnerabilities, and perspectives that emphasize other special task challenges.

(2) No–Try to create VE perspectives for effective observation of key task actions through image manipulations such as creation of transparencies, fish-eye magnification, etc.

d. Identify the most important component lessons or visual pattern distinctions that are readily rendered as visual (or visual and verbal/auditory) examples or illustrations. Plan to create demonstration vignettes for each component lesson or important visual pattern. Limit the number of such lesson vignettes in order to keep the total demonstration to a manageable length for the trainee.

e. Are any of the critical visual elements subtle or otherwise difficult to see and/or understand at normal speed and with normal perspective and without elaborating explanation?

(1) Yes–Plan to use highlighting, zooming/magnification, multiple perspectives, verbal annotation, etc. to draw attention and explain features and issues.

(2) No–Check again by interviewing trainees who have the most difficulty with initial standard demonstrations of the task.

f. Are there any especially prominent (and relatively likely and performance-critical) errors in task performance that deserve to be explicitly addressed? Do standard tutorial presentations specifically identify certain errors and instruct the trainee as to why and how to avoid them?

(1) Yes–Plan to include component demonstrations of no more than a few of the most common and critical errors, using visual and auditory elements to make it clear that these are errors to be avoided and not to be confused with recommended performance. For each case,

provide a clear explanation of what is wrong with the erroneous performance, why it is wrong (i.e., consequences), and how to avoid making this error. Before and after presenting error demonstrations, make sure to present correct performance demonstrations so as to ensure that the trainee especially learns and remembers the correct task performance and avoids any possibility of confusing incorrect with correct performance. Make sure to provide at least equal time to the demonstration of correct performance relative to all error demonstrations to ensure that correct performance is firmly fixed in the trainee's memory, with no chance that the trainee might confuse any presentations of errors with correct performance.

(2) No–If the pattern of errors is too diverse with each specific error being relatively unlikely, then avoid presentation of specific error demonstrations because they are unlikely to be very helpful and the downside risk of later confusion with prescribed performance would be too much of a concern.

g. Do significant aspects of task performance need to be altered to contend with typical variations in environment and contextual conditions? Are there multiple distinct key lessons/principles to be learned in association with distinct environment/context conditions? (Must determine to what degree the relevant lessons/principles can/should be learned through verbal explanation versus demonstration examples for each case, though combinations of the two are likely to be especially effective.)

(1) Yes–Identify a few distinct environment/context condition cases that effectively bracket and represent the key variations of concern. Plan on separate demonstrations or demonstration variations for each, in each case highlighting the key differences between the cases and how the trainee should be able to identify which case is most relevant to any situation that arises.

(2) No–At least at the current stage of training, variations in environment and context are not significant concerns. A single demonstration of recommended performance within a nominal context is sufficient.

h. Are there significant variations in correct task performance, with distinct variations being more or less conducive to the capabilities and limitations of individual trainees?

(1) Yes–Identify a few of the primary alternatives in style or procedure for acceptable task performance and develop explanations for how trainees should determine which is most appropriate for them to adopt individually. Plan on separate demonstrations for each of the primary styles/procedures, in each case highlighting the key differences and how the trainee should be able to identify which is most suitable.

(2) No–At least at the current stage of training, variations in procedure and style are not of concern. A single demonstration with a single procedure and style of task performance is all that is warranted.

i. With respect to each area of identified or expected specific task performance difficulty, is the difficulty mainly due to:

(1) Difficulty in identifying the triggering conditions for special action (including cognitive action as well as physical action)? Plan to develop segments of the demonstration to focus on how to recognize the triggering conditions and how to avoid the most common errors in recognition.

(2) Difficulty in remembering to attend to the situational indicators and then perform the appropriate action? Plan on providing repetitive emphasis on the need for vigilance in this area along with explanation of why it is important and possibly also offering detailed guidance as to how to manage the attention process (e.g., such as the instrument scan patterns that aircraft pilots are taught).

(3) Difficulty in understanding how to perform the appropriate action correctly? Identify the areas of significant difficulty in terms of cognitive and physical actions. Problems in cognitive areas should be addressed through explanation of required cognitive processes (what, why, how). Potentially problematic subsidiary processes should also be considered for attention, especially if a significant portion of the trainees are expected to have difficulty with the subsidiary processes. Problems in physical aspects of performance should be addressed through explicit demonstration of correct performance with highlighting of performance in the areas of specific difficulty. Demonstration of frequent errors should be considered in accordance with Guideline 6.

(4) Difficulty in actually performing the required action correctly despite knowing when and how to do it? This difficulty cannot be further aided via demonstration but rather requires interactive experiential training with feedback to achieve improvement.

j. Most training will be concerned with complex skills that will be composed of integrated combinations of simpler skills to accomplish an objective. In demonstrating the complex skills, we need to consider to what degree we should assume that the trainees have mastered the simpler component skills and, hence, to what degree the training could benefit from remediative demonstration of those simpler skills.

(1) Potentially problematic component subskills/subtasks can be identified (e.g., through observation, analysis, evaluation of performance or interviews with trainees). Plan to develop concise segments of review/remediation for subskills/subtasks of concern. Try to distill review pieces to minimal length by employing cues to salient elements of earlier training on those subskills/subtasks. Alternatively, plan to provide elements in periodic evaluations of trainee performance to identify any deficiencies in relevant subskills/subtasks and then offer remedial demonstrations only upon identification of the need.

(2) Even if there is no initial indication of any specific subskill/subtask performance deficiencies in the target population at the intended stage of training, plan to incorporate

elements in periodic trainee performance evaluations to determine if such problems might eventually arise, then would be addressed as described in (a) above.

k. Are the focal tasks primarily concerned with the gross physical interactions of multiple people, in the finer physical actions of individuals, or in verbal and gestural communications between individuals?

(1) Gross physical interactions of multiple people–Plan to use a tool like VBS2 for video generation.

(2) Fine physical actions of individuals–Plan to use a tool like Gamebryo.

(3) Verbal and gestural communications between individuals–Plan to use a tool like VCommunicator.

Vision for Overall VESTED Authoring Use Model

The VESTED Demonstration Specification application enables users to author demonstration-based training videos through a combination of training techniques used in conjunction with a storyboard creation tool. Additionally, VESTED users will be able to utilize the multi-player functionality of the underlying system game-engine in order to create complete instructional demonstration videos. Traditionally, this type of work was the domain of high-end animation and video packages, such as 3DStudio Max® and Final Cut Pro. These packages required a great deal of skill from their end users and frequently had steep learning curves before adequate results could be obtained.

Before continuing, it is important to articulate the demonstration authoring use-model envisioned for VESTED. Figure 4 below depicts a canonical use-model for VESTED demonstration authoring comprised of three roughly sequential steps:

a. Demonstration specification step where the author identifies the specific learning objectives to be modeled, reviews demonstration authoring guidelines, and creates a set of demonstration storyboards that reflect the target behaviors.

b. Demonstration video generation step whereby the demonstration author utilizes the specific game-based environment to instantiate the behaviors represented in the storyboards (thus generating a set of raw intermediate videos).

c. Video mixing step, which involves the importation of those intermediate videos into a commercial-off-the-shelf video mixing tool whereby post-processing can be performed to create the final demonstration videos.

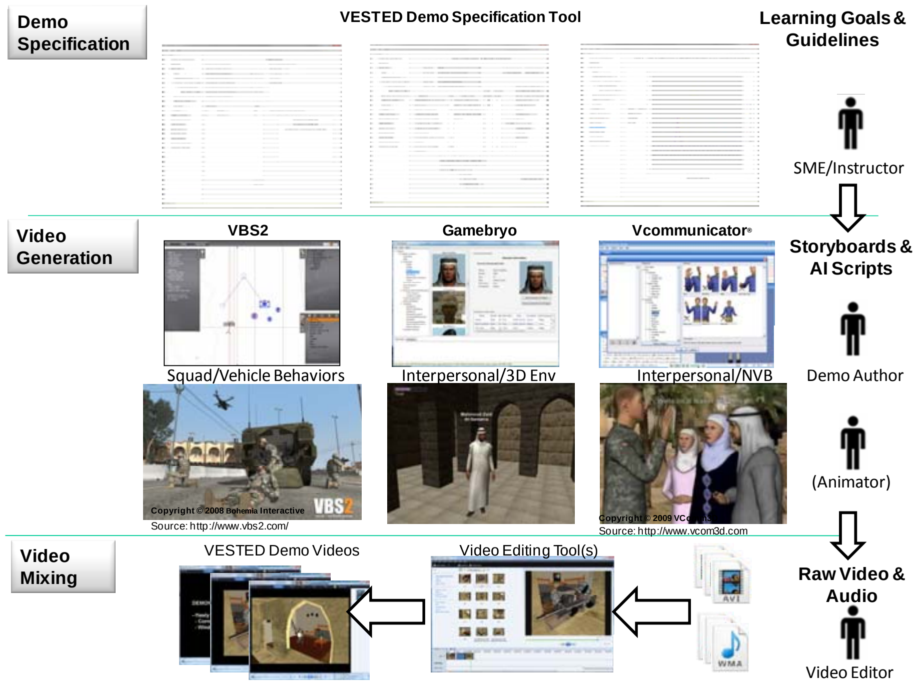


Figure 4. VESTED authoring use-model.

We anticipate that the demonstration pipeline for VESTED demonstration creation will involve a number of users within the use-model described above. First, we anticipate that the articulation of learning goals and the creation of demonstration storyboards during the demonstration specification step will typically be performed by a domain subject matter expert (SME) well-versed in the training materials being demonstrated. Second, we anticipate that the demonstration author, most likely an engineer, will typically work closely with the demonstration author in order to instantiate the demonstration using the authoring toolset within a given game-engine in order to generate a body of raw intermediate videos. Digital animators may also be required during this step if a given game-engine does not provide a required animation. Lastly, we envision that the creation and compositing of a final demonstration video will be done by a video-editor working closely with the SME who created the demonstration storyboard in order to ensure that the desired instructional aspects of the demonstration are reflected in the final demonstration mixing process.

Demonstration Specification - Design and Storyboarding

Demonstration Specification is the VESTED process whereby a demonstration author selects the specific learning goals to be demonstrated and then elaborates those requirements into a detailed design for the demonstration. Based on selected learning goals, the VESTED authoring tool compares those selected goals to the underlying demonstration guidelines to provide recommendations about content sequencing, choice of instructional strategies (e.g., comparisons and contrasts), level of fidelity, and so forth. Design decisions are represented in the form of demonstration design hypotheses (i.e., cases), each of which is linked to a rationale

and to sources of data. During the subsequent storyboard stage, the author will be able to define high-level demonstration scenes and how they are to be ordered and sequenced.

For example, an author may want to construct a demonstration that focuses on the MOUT domain in the instructional context of providing a building-clearing scenario, but may also want to focus on the role of an individual within that team context. To do so, the VESTED author would select a MOUT domain template. This template would configure the authoring tool to visually highlight the specific VESTED functions most relevant to the authoring process for a MOUT demonstration, such as pertinent visual scene props, use of characters if applicable, details of blue/red/neutral forces, character movement, object behaviors, and use of mixed media (such as imported videos). Additionally, by specifying the "individual vs. team" template, the VESTED authoring tool provides access to tailored guidelines relative to this form of demonstration. When the research literature warrants it, these guidelines could be expanded to address what perspectives to include in demonstration displays, whether to use demonstrations of common errors, whether and how to employ distortions in time scale, and how to handle decision points within the task being modeled. In addition to these forms of guideline support, we anticipate including a library of hierarchically organized hypertext reference documents (typically field manuals) to provide rapid access to doctrinal aspects of each supported domain template (e.g., MOUT, cultural familiarization, etc.) and to allow demonstration authors to include linkages between doctrinal references and authored demonstrations for pedigreed VESTED demonstrations. A formative set of the training objective templates include the following:

- Individual vs. team–In some cases, the objective will be to demonstrate just the task performance of a single individual (even though that person may be part of a team in their broader responsibilities), and in other cases the objective may be to demonstrate how to coordinate individual performance with the performance of other team members.
- Gestalt vs. detail–The objective may be to present the complete integrated gestalt representation of the focal task or activity, or it may be primarily just to focus on a few detailed aspects of the activity on the assumption that overall gestalt is already well-enough understood by the target audience. Although some complete integrating demonstration framework may still be warranted in many of the cases where the main focus is on detail, the detailed objective may warrant a very coarse representation outside the vicinity of the focal details. Where details are to be the focus, some of the main options will likely include: first-person physical or speech behaviors, third-person physical or speech behaviors, external visual/speech/sound cues, and abstract concepts (e.g., line of sight, field of view, response time).
- Nominal vs. adaptive–The objective may be to convey the image and basic understanding of a single, nominal, correct way to perform the task, or alternatively to try to convey a deeper understanding of the reasoning why that procedure is generally appropriate and thereby to instill a capability to adapt the procedure effectively when the situation does not evolve according to the assumptions of the nominal scenario.

- Correct performance vs. errors–We assume that in all cases we will want to provide a demonstration of correct performance and in some cases that may be all that is warranted. But in other cases, it will also be important to present demonstrations of common errors, especially where the primary focus of training is to avoid common mistakes (such as in training of safety procedures or in cultural sensitivity where the main focus is often on identifying what not to do).

Demonstration Video Generation –Intermediate Media Generation

Demonstration Video Generation is the VESTED process whereby a demonstration author utilizes a set of environment assets (pre-supplied 'whole' environments or 'library-based' assets), places actors (blue/red-forces), defines behaviors (including avatar movement and positioning), iteratively reviews demonstrations and refines, and generates raw source videos (presumably from multiple camera perspectives). A range of VESTED authoring concepts were identified and are discussed below.

Sandboxed environments contain world geometry and enemy AI already positioned in the environment. The author's control is limited to removing or modifying the behavior of the pre-placed enemy AI, changing camera views, and adding simple events (e.g., audio events like gun-fire, etc.). Existing AI middleware solutions often require heavy markup of the environment and tweaking for proper behavior. This approach requires that pre-constructed environments are provided in a library so that the user does not need to understand the nuances required to set up an effective environment using this type of AI approach. Through the use of preconfigured environments, the users' learning curves would be reduced and they would be able to begin creating demonstrations much more quickly. Use of preconfigured environments also provides a possible content creation mechanism where updates can be offered for the application to provide novel locations and/or enemy behaviors for existing packages.

Demonstrations created through a *multiplayer-capture*-based design involve recording the actions of multiplayer participants coupled with a playback mechanism from user-selectable and editable 'virtual' cameras. Setting up a scenario for capture is limited to choosing an environment and connecting to the other participants. After the scenario has ended, the author reviews the scenario playback, moving as desired between placed cameras, and records video as desired from all instructionally meaningful camera views. Multiplayer's most obvious limitation is that it potentially requires a large number of skilled participants to create an effective demonstration. However, the removal of any AI entities from this design helps reduce the cost of development.

Demonstrations created through *ghosting* are similar to the capture through the multiplayer approach with the exception that a single user plays all parts of the scenario. To accomplish this, an author would move through the environment once for each actor in the scenario. As the author adds each new character to the scenario, the previous runs are visible as ghosts in the environment. Using this layering approach, a single user can build up a complex scenario over time. Once the author is satisfied with the composition of the scenario, it can be played back and the results loaded into the same non-linear editing interface used in the

multiplayer capture approach. Ghosting places a high cognitive load on the author and is poorly suited for large scale simulations containing many entities.

Custom demonstrations require the author to manually place all content, using both an interactive 3D environment coupled with *script actions* using a timeline/track interface. This approach can be mixed with limited AI behaviors to help ease the burden on the author (e.g., building a script behavior to 'sit' that positions the character correctly next to a chair object and correctly plays the necessary animations required to add realism to the invocation of the command). This paradigm gives the most control of all of the approaches, but the tradeoff is that the scenario creation process itself is highly iterative and requires 'trial-and-error' as behavior scripts can interact in ways that lead to unpredictable behaviors – thus requiring considerable refinement.

Demonstration Mixing – Instructional Integration and Final Production

Demonstration Video Mixing is the VESTED process whereby a user imports source videos (from above), selects specific source video 'tracks' (i.e., 'views'), includes 2D overlays and animations, records instructional narrations, composites other training effects (e.g., flash lighting), and generates final video renders. The figure below illustrates a high-level set of training-constructs based on analysis of existing MOUT video demonstrations. The goal was to identify a small set of demonstration *constructs* and map those to training *intent*. Five specific construct types were derived from the video and mapped to corresponding intent types (by way of example) and are visually depicted in Figure 5.

The description of each construct and training intent include:

- Enumeration –provide a 2D text/graphic overlay of concepts with a particular emphasis on knowledge-priming.
- Conceptualization –provide a 2D or simplified representation of demonstration tasks with a particular emphasis on knowledge-priming.
- Modeling – provide $1^{st}/3^{rd}$-person point-of-view presentation of tasks/procedures being modeled; this has been the heretofore focus of the VESTED demonstration authoring concept of operations which includes core enabling components such as a 3D environment coupled with an AI-based authoring feature-set.
- Composited – provide additional cues to the modeled behaviors such as a 2D overlay.
- Focus cuing – use of visual and auditory cues, such as flash-lighting, high-lighting, and narration, to draw attention to salient cues and concepts within the modeled task.

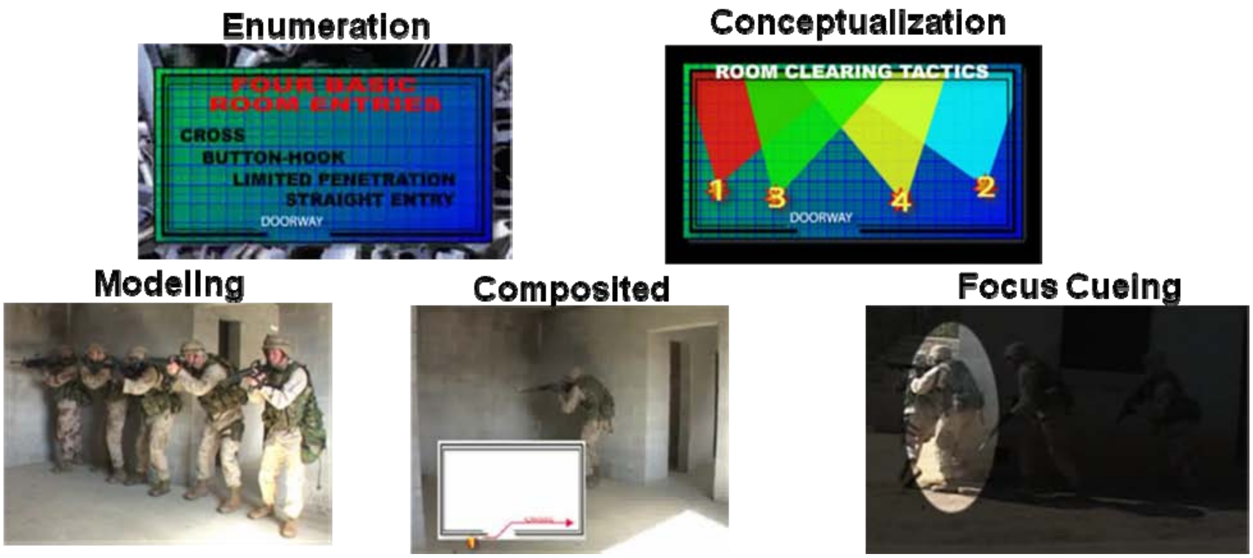


Figure 5. VESTED instructional content type examples.

The Video Creation steps described in the candidate use-model above are premised on a game-based 3D environment. It is likely that for VESTED users, the Video Mixing steps outlined above may best be done using third-party commercial tools for non-linear video-editing (e.g., Adobe Premiere Elements, Sony Vegas, Roxio Creator, Nero 9, Pinnacle Studio).

Test Case Applications

Test Case Selection Criteria

In the course of VESTED development efforts, we found that it was essential to select some specific application cases in order to focus our design efforts. There is a broad range of procedural learning areas in which demonstrations are potentially beneficially applicable, with these areas of relevant applicability varying over several key dimensions. Important differences in these areas include particularly:

- Whether the task is primarily physical/psychophysical or primarily cognitive;
- Whether the task is strictly linear (always the same steps in the same order) or characterized by multiple conditional branching;
- Whether the task is performed by a solitary individual or as an interactive activity involving cooperation or competition with other people;
- The kinds and amounts of declarative knowledge required to learn the task;
- The kinds and amounts of recognitional knowledge required to learn the task.

We chose two different test cases representing distinctly different configurations over these and other task characteristics, one for the first year efforts which addressed VESTED product conception and another for the second year efforts which were concerned primarily with product implementation. The first year test-case that we selected is one of the key tasks within the area of Military Operations in Urban Terrain -- the task of finding and occupying a hasty firing position. This task is primarily physical/psychophysical, minimally linear (mainly focusing on learning under what conditions you should use each different type of firing position and posture), somewhat competitively interactive with adversary personnel, and with little need for declarative knowledge but considerable need for recognitional knowledge (concerning types of categories of terrain, protective structure, and tactical situation). The second year test case is concerned instead with the standard task for a battlefield medic of performing a cricothyroidotomy (better known as a tracheotomy) which is a primarily linear task that is both cognitive and physical and requires considerable declarative and recognitional knowledge.

Year 1 Test Case – MOUT Hasty Firing Position

We developed a VE concept demonstration midway through Year 1 of the VESTED project. The purpose of creating the interim demonstration was not to show how a VE demonstration is created using an early stage prototype of the VESTED system; rather it was motivated by the need to inform the development of the system and the authoring guidelines. It provided the means by which we could walk through the processes of demonstration specification, video generation, and video mixing to unearth issues early in the system development life cycle that would otherwise go undetected until much later and possibly too late.

A hasty firing position is “a position from which the Soldier can place fire upon the enemy while using available cover for protection from return fire. The Soldier may occupy it voluntarily or [the Soldier] may be forced to occupy it due to enemy fire. In either case, the position lacks preparation before occupation.” (Army Field Manual (FM) 3-06.11 and Marine Corps Warfighting Publication (MCWP) 3-35.3). Hasty firing positions include firing around corners of buildings and walls, through windows, from a loophole, from the peak of a roof, and when there is no firing position or cover available. To limit the scope of our concept demonstration to a manageable size, (meaning the ability to develop the demonstration in a relatively short period of time yet still provide meaningful insight into the demonstration development process), we chose to concentrate on firing around buildings and walls and through windows. Other hasty firing selection criteria included choosing a practical example of procedural and cognitive knowledge acquisition and the confidence that the demonstration was amenable to depiction in a virtual environment, initially VBS2.

As we have previously discussed, demonstrations should be driven initially by learning objectives or goals. So the first step in the development of the concept demonstration was the identification of learning goals for hasty firing positions as well as the general principles and key factors to consider from which the learning goals were derived. For hasty firing positions, (FM) 3-06.11 offered two key factors, protection and concealment, and nine considerations:

- Make maximum use of available cover and concealment.
- Avoid firing over cover; when possible, fire around it.
- Avoid silhouetting against light-colored buildings, the skyline, and so on.
- Carefully select a new fighting position before leaving an old one.
- Avoid setting a pattern; fire from both barricaded and non-barricaded windows.
- Keep exposure time to a minimum.
- Begin improving your hasty position immediately after occupation.
- Use construction material that is readily available in an urban area.
- Remember that positions that provide cover at ground level may not provide cover on higher floors.

We derived the following learning objectives from these key factors and general principles:

- knowledge of how to remain covered while occupying a hasty firing position;
- knowledge of how to remain concealed while occupying a hasty firing position; and
- skill in positioning appendages so as to minimize exposure to enemy fire.

The second step in the development process included the construction of a script, or storyboard, which provided a storyline that was broken down into demonstration segments. Initially, we did not have a storyboard template, thus we created one. Each demonstration segment included: transition into the segment, the segment’s main modality (video, text, etc.),

content frame, camera perspective, animation, narration, music, and transition out of the video segment.

We populated the storyboards utilizing both the initial set of demonstration authoring guidelines discussed above and the specified learning goals. The sequence of demonstration includes presentations of both prescribed and proscribed behaviors (i.e., mixed model as referred to in the BMT literature). The sequence of the segments was as follows:

- Presentation of learning goals
- Presentation of key factors and general principles
- Definition of hasty firing positions
- Firing around buildings/walls prescribed behavior
- Firing around buildings/walls proscribed behavior
- Firing through windows prescribed behavior
- Firing through windows proscribed behavior
- Review of firing around buildings/walls prescribed behavior
- Review of firing through windows proscribed behavior
- Review of learning goals

The storyboards were then used by the VE development team (i.e., gaming environment developer and graphic artist). Other steps in the concept demonstration development process included:

- Art development
- Voice narration
- Music selection
- Video editing
-

Figures 6 and 7 below show two screenshots from the concept demonstration. Figure 6 shows the proper technique for firing around a building–the Soldier is in the prone position and is using the short stocking technique.

Figure 6. Correct firing position around buildings.

Figure 7 depicts the proper firing technique from inside a window. The Soldier is kneeling to reduce exposure and is back in the room to limit silhouetting.

Figure 7. Correct firing position from inside a window.

Year 2 Test Case – Cricothyroidotomy

A cricothyroidotomy (CRIC) is a procedure that is performed on a patient who has an air passage that is blocked above the cricothyroid structure (Adam's apple region). This is primarily a linear task, though most of the major steps in the task involve declarative knowledge, recognitional knowledge, and cognitive deliberations. The initial step of determining whether or not the procedure is warranted for any particular patient is rather challenging (considered the severity of the blockage and the history of all other measures that were attempted and why they failed) and accordingly is not included in this test-case; rather we focus on how to perform the procedure once the decision has been made.

The assumed target audience for training in this test-case consists of individuals in early stage training to serve as battlefield medics who have completed Army basic training and satisfied all selection criteria. We assume that trainees have been separately trained or presented with demonstrations regarding the following initial steps of the CRIC procedure:

- How to make the decision of whether or not to perform the CRIC procedure.
- How to assemble all of the required materials for the CRIC procedure.
- How to prepare the patient for the CRIC procedure.

Following the viewing of this demonstration video, trainees are assumed to receive interactive training in the CRIC procedure.

The primary training objectives to be addressed by the demonstration are that after viewing the demonstration video, the trainee should be able to:

- List all steps in CRIC procedure in correct order
- Locate anatomical landmarks
- Find appropriate location for skin incision
- Find appropriate location for tracheal incision
- Explain how to handle most common problems in anomalous neck anatomy
- Explain how to determine if airway is patent after spreading tracheal incision

Based on all of these requirements, we formulated the following demonstration outline which served as the focal material for development of all of the VESTED interface screens (and serves as the example test-case in all of the interface screens depicted in this report):

(1) Introduction
- Title
- Credits
- Target audience

(2) Training objectives

- Assumed prior training
- Specific training objectives
- Assumed subsequent training

(3) Full run-through demonstration of basic CRIC procedure
Demonstrate standard procedure in continuous, real-time mode without any special problems. Narration should explain major steps and highlighting or zooming may be used to draw attention to focal activities.

(4) Drill-down elaboration

- Outline drill-down segments
- Anatomical landmarks
  - Basic anatomy
  - Problem anatomy
- Skin incision
  - Rationale for vertical incision
  - Problems with excessive bleeding
- Tracheal incision
  - Rationale for horizontal incision
  - Stabilizing thyroid cartilage
  - Risk of esophagal perforation
  - Opening incision
- Tube insertion
  - Verify correct insertion
  - Verify bilateral breath sounds
  - Rectifying if ventilation is unilateral
- Most common complications
  - Hemorrhage
    - Causes – laceration of superficial capillaries or major vessels
    - Treatment – use direct pressure or ligation if necessary
  - Esophagal perforation
    - Causes -- too deep of an incision or forcing ET tube into esophagus
    - Treatment – surgical repair at higher echelon of care
  - Subcutaneous emphysema
    - Causes – too wide of an incision and air leaking from insertion site under skin
    - Treatment – none necessary, will spontaneously resolve within few days; placement of petroleum gauze dressing around incision site will help reduce incidence

(5) Review of complete procedure. Continuous demonstration of complete procedure with accompanying narration to explain special issues and problems and review to avoid problems and handle them if they arise, possibly slowing or pausing demonstration to provide opportunity for appropriate amount of narration.

In order to better understand the challenges involved in making a VE model and video to accompany this kind of demonstration, we undertook this effort in a limited fashion. Example views generated in this effort are illustrated in Figure 8 and 9.

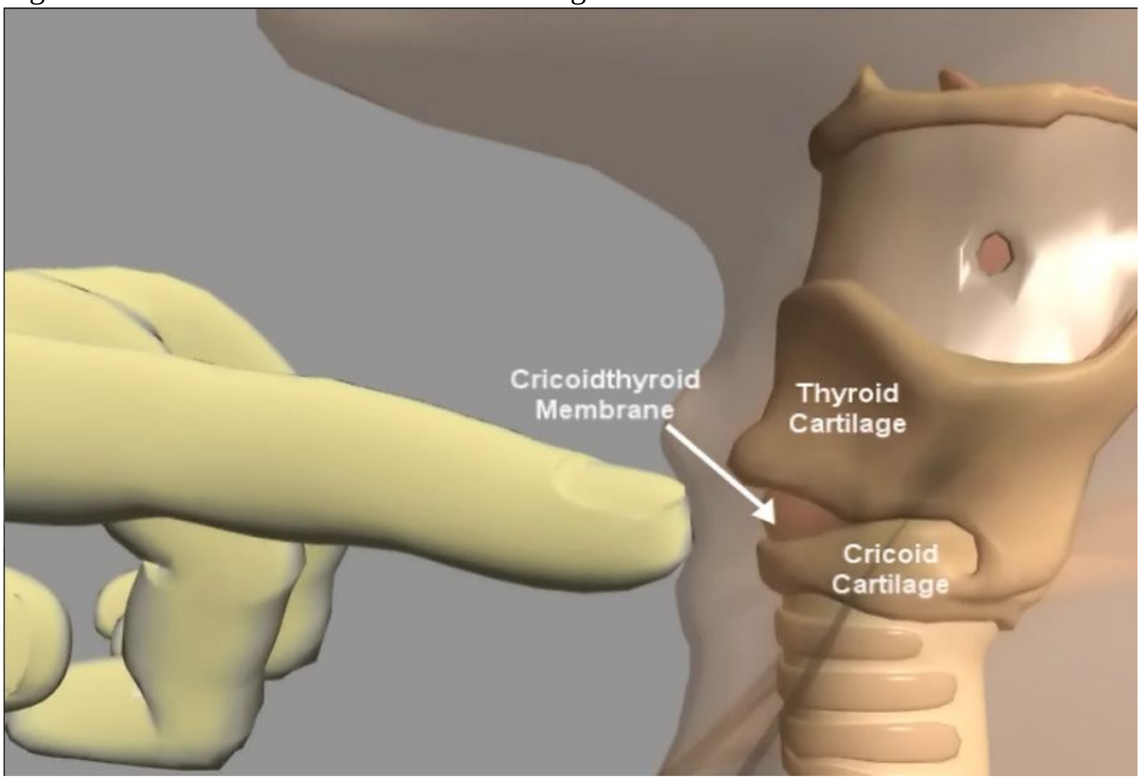


Figure 8. View of cricothyroid anatomical structure from VE model.

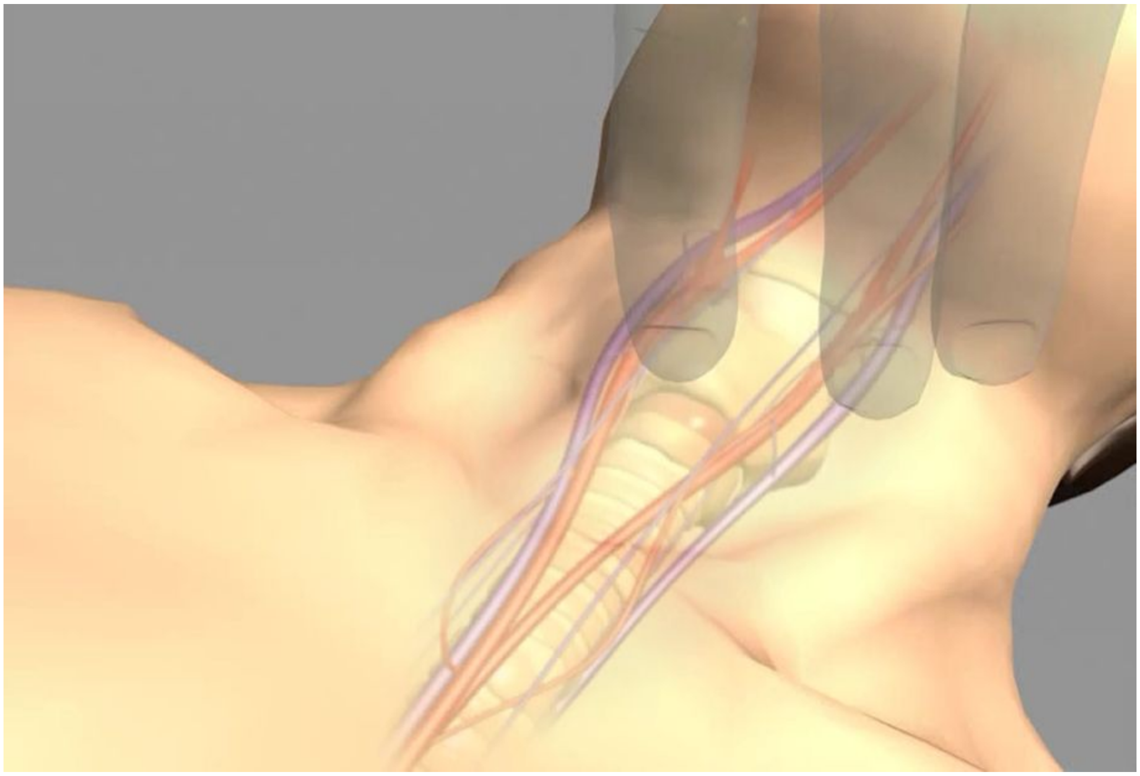


Figure 9. Use of transparency to highlight anatomical structures.

Demonstration Specification Development

Who are the users?

Of course, there are many people and teams developing VE-based training products, with many successful such products in prominent use, such as in the case of “America’s Army”. However, it is our suggestion that most of these efforts have arisen through processes other than a ‘normal’ training product development process. We conceive of the normal development process as one in which a training requirement is identified along with various relevant constraints (budgets, schedules, success criteria, etc.) followed by a systematic process of formulating alternative strategies to satisfy that requirement and then efforts to formulate and execute an effective implementation plan. Instead, most existing VE training products have been produced primarily as demonstrations of technological feasibility, vehicles of research investigations, objects of R&D programs (such as the VESTED project reported here), or cases of opportunistic leveraging on VE products originally produced for other purposes (such as for the various computer games that have been found to be adaptable for training purposes; Belanich, Sibley & Orvis, 2004).

Thus, we expect that the people and teams who developed the existing VE training products may be distinctly different from the users that we hope to support for the more normal processes to produce training development products. Clearly, teams that have produced demonstrations of VE technological feasibility are heavily weighted toward leading edge VE computer software skills and development facilities. The same is generally true for teams pursuing research investigations. In fact, for these teams as well as those adapting existing products, there is likely to be considerable flexibility with regard to what training challenges they take – what training domains and requirements that they sign up for. If you are just demonstrating a technology, then it will probably not matter much if the chosen application is for a medical procedure or for operating a military weapons system, so long as the demonstration effectively illustrates how the technological features might serve to address some useful training purposes. However, we assume that in the normal training product development process, the choice of application area is not so arbitrary – the training requirement is typically established completely independently from the potentially relevant technologies.

For VESTED, we envision similar user communities and characteristics. However, we also envision a very broad range of types of potential users for both products, ranging from the low-echelon, forward-deployed individual who might be creating some “just in time” training product, such as to train unit personnel in how to defeat some new IED variant that has just appeared in the local area, to established organizations at higher echelon levels with charters for the production and maintenance of widely used training programs. Thus, the user may be a single individual performing the entire production effort solitarily, or it could be an individual who leads or works within a larger organization, or it could be a team of people working together with the VESTED tool. For the design of the VESTED tool, it is particularly important to establish the kinds of relevant expertise that the user or user team will or won’t possess. At least five general types of expertise must be considered:

- Training pedagogy
- Subject matter expertise in the target skill area
- Training product production skills
- Artistic skills (manual art, digital art, photography, etc.)
- Software skills (especially in VE, multimedia tools, etc.)

We expect that most users will have some expertise in the area of training pedagogy, with a good understanding of the training objectives for the intended product and how it might fit into any larger training program. However, we expect that there may be wide variability with regard to whether or not the users have some or little expertise in the other areas where they may need to draw on other sources within or outside of their production team.

Design

Because of its focus on linear demonstration videos rather than multiple branching interactive scenarios and its consideration of modalities other than VE for production, VESTED must provide a variety of functions. Since VESTED addresses only the design, planning, and storyboarding phase of application production and not the actual video creation, it does not get entangled with the problem of a complex boundary between its functionality and that of the other video production tools that might be required. Still, there is a considerable challenge to the user to determine how to pick and choose among the various relevant media (i.e., VE, photography, manual artwork, music, narration) in order to produce an adequate training product that will satisfy training objectives and production constraints. This challenge is compounded by the complex options that are often posed by availability of various kinds of legacy materials in some of the media which may address some of the production needs to varying degrees. A further related issue is the consideration of the potential value to other future training projects and products of the results of the current effort, which is especially important for cases where an elaborate VE product is to be constructed.

Although the VESTED user will not be required to work in a strictly linear, sequential fashion in developing the specification and evaluations of options for training demonstrations, we will assume a default linear sequence for our description of the VESTED interface design. We expect that most users would follow roughly this sequence for their initial specifications of their demonstration requirements and ideas, but we also expect considerable idiosyncratic iteration following the “first pass” of specifications and evaluations in order to adjust and refine the initial demonstration plans and resolve problems identified in the evaluation results.

The primary interface screens and their presumed sequence of initial use are as follows:

- Specifying requirements and linking to general guidelines
- Objectives specification
- Demonstration outline
- Connecting Objectives to Outline
- Case construction & benefit estimation

- View benefit evaluations
    - Tabular display of single case benefits
    - Graphic display of single case benefits
    - Tabular display of differences in benefits between two cases
    - Graphic display of differences in benefits between two cases
- Create and view cost estimates
    - Specify foundation elements for each case
    - Specify cost element details for each case
    - View cost summary for each case
    - Specify future reuse profile for each case
    - View cost projection for each reuse profile

The six major headings in the above outline of VESTED interface screens represent the six distinct functional areas through which VESTED aids the user in specifying, evaluating, and deciding on a plan for construction of a training demonstration. The user begins with the specification of training requirements and objectives and with formulation of an outline for the training demonstration, with these two steps being optionally performed in either order. Both of these first two steps must be completed before the third and forth steps of “connecting objectives to outline” and “case construction & benefit estimation” can be accomplished, and the third step must precede the fourth. Although this fourth step is logically really a composite of two distinct functions, it is represented as a single step in the interface because it seems most efficient for the user to specify the estimated benefits for each of the most detailed segments of the storyboard outline just as the concept for media implementation of that segment is conceived in specification of the storyboard outline. The final two functional areas, which again can be addressed in either order, are viewing of evaluation results and creation and viewing of cost estimates.

In the following subsections, we describe the interface screens associated with each of these functional areas.

<u>Specifying requirements and linking to general guidelines</u>. Although we have determined that the current research literature does not seem to support the compilation of any very detailed design guidelines for the design of training demonstrations, we have identified a few general guidelines (as discussed above in “Process for Guideline Development”) that are driven by some high level and easily identified characteristics of the training requirement and target tasks. Figure 10 illustrates one of these screens.

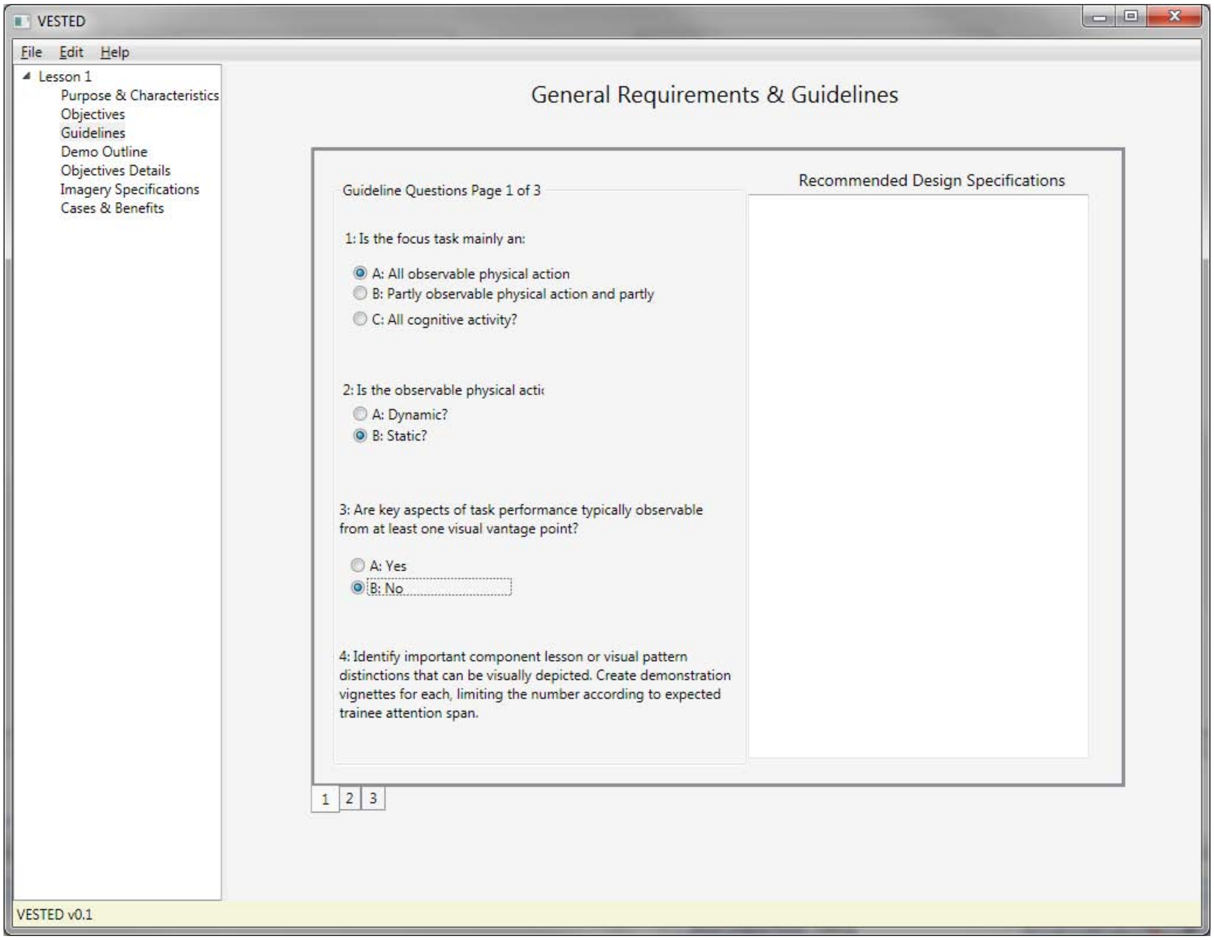


Figure 10. Specification of general requirements and links to high-level guidelines.

In the current stage of VESTED tool implementation, it is intended that these guidelines are to be integrated into the design process through the discretion and ingenuity of the user, with no direct linkage within the VESTED software between these initial specifications and later stages of detailed design screens. However, it is our expectation that experience and user feedback from initial VESTED applications will enable us to formulate increasingly detailed guidelines along with direct integration of those guidelines into many of the screens addressing detailed design issues.

While we have determined that formulation of predefined detailed guidelines is currently an elusive goal, we believe that it is important for the user to develop detailed connections between the training objectives for the demonstration and the design features of the demonstration. This is accomplished by requiring that the user specify those detailed training objectives before developing the design. The VESTED user starts by defining training objectives in accordance with a standard hierarchy of terminal training objectives (highest, most general, and most expansive level), subordinate training objectives (middle level), and enabling objectives (lowest level and most specific). The user is also asked to classify each enabling objective in terms of a small number of predefined categories (see Figure 11). In particular, the following major categories of training objective have been identified as relevant:

- Types of knowledge:
    - Declarative knowledge
    - Procedural knowledge
    - Conceptual knowledge
    - Recognitional or perceptual knowledge
- Moderators of knowledge processing
    - Integration of separate knowledge elements into an interconnected whole
    - Link to prior knowledge/experience
- Moderators of training dynamics
    - Orientation or focusing of the trainee's attention
    - Motivation

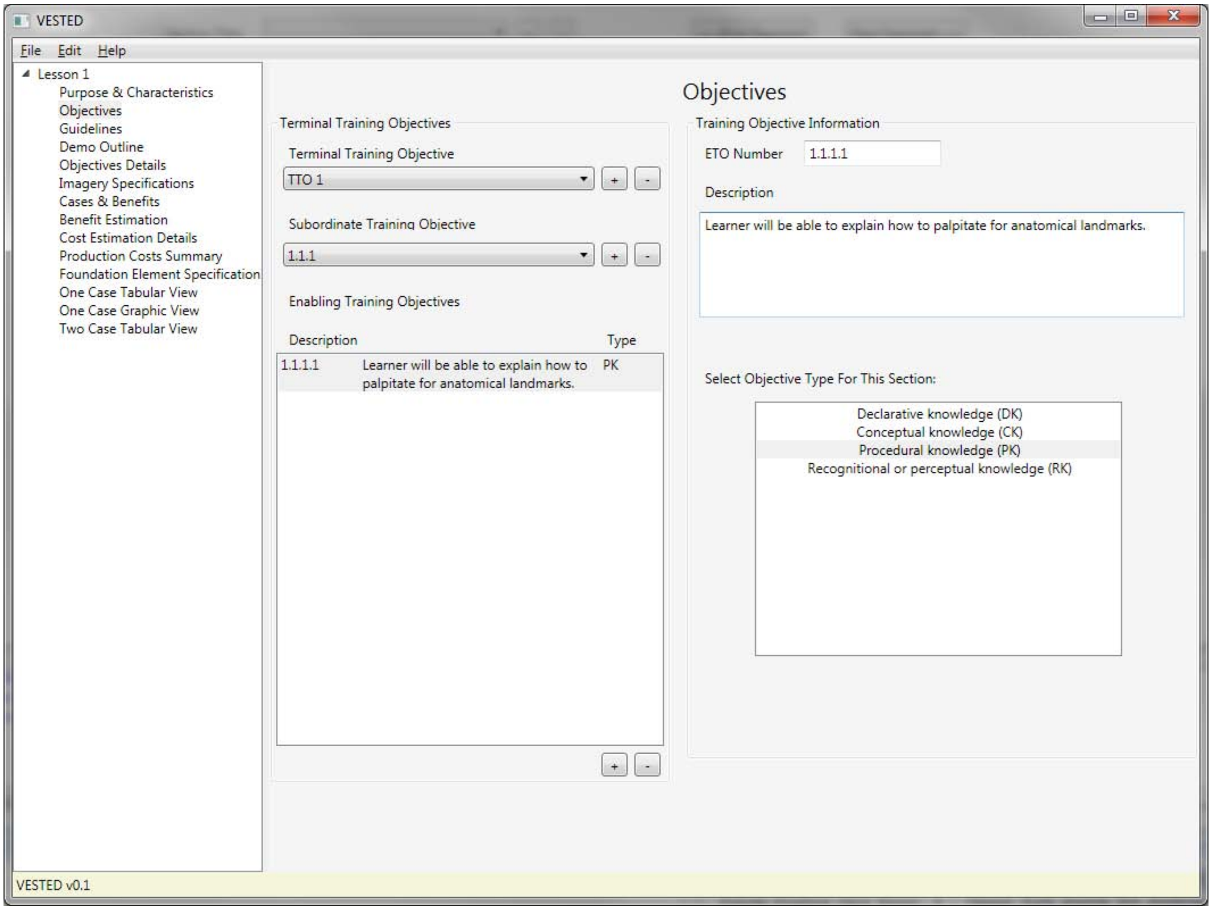


Figure 11. Specification of training objectives.

<u>Demonstration outline</u>. VESTED requires the user to specify an outline for the needed demonstration in the form of a storyboard structure which will serve subsequently as the basis of decisions about what media and what legacy materials to employ for application production. Storyboards are conceived as a sequence of elements constructed within the hierarchical organization of sections (highest level), frames (middle level), and segments (most detailed level), with each at the segment level tied directly to at least one specific training objective that is

designed to address the higher level training goals for the product. Figure 12 represents the Demonstration Outline screen. It offers the user a collection of standard options for the outline consisting of the following:

- Titles
- Credits
- Objectives overview
- Tutorial overview
- Full procedure run-through
- Drill-down of procedure steps
- Drill-down of procedure variations
- Drill-down of special conditions
- Drill-down of common errors
- Review of full procedure
- Take-away points
- Summary

Although we would generally expect titles to go first and summary to come last, it is not hard to imagine all sorts of orderings of these pieces for different types of material, alternative training objectives, varying target audience characteristic, and individual training styles. Accordingly, the user is allowed to select from and order these elements in any sequence along with creating any other outline heading that the user might conceive in other relevant categories.

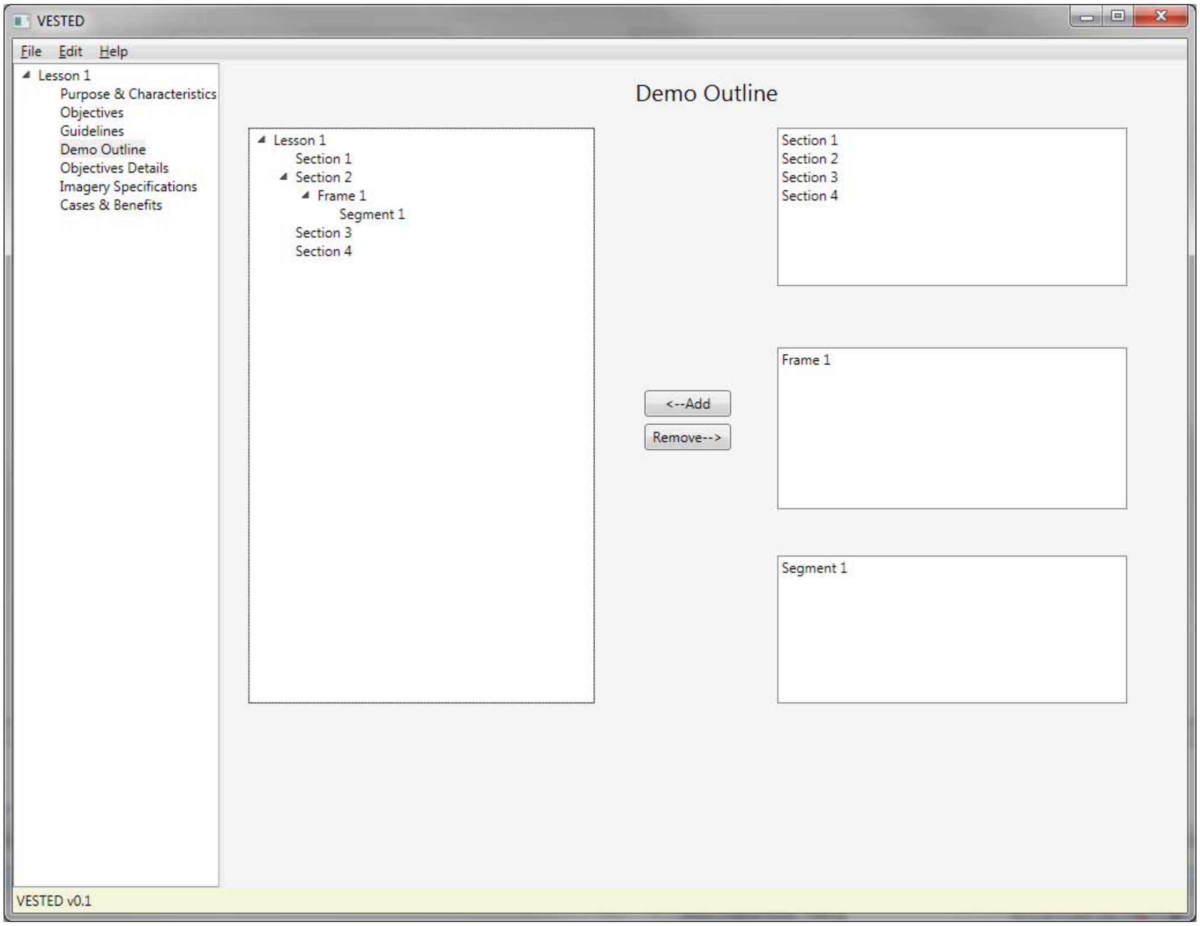


Figure 12. Creating the demonstration outline.

Connecting objectives to outline. The fundamental principle of VESTED, that concepts for training demonstrations be driven by the identification of specific training objectives, requires that at least one objective be associated with each sequential segment of the storyboard design (which consists of a linear sequence of segments at the most detailed level of representation in VESTED). In the third major screen and functional area (see Figure 13), the user is asked to associate one or more enabling objectives to each segment in the demonstration outline.

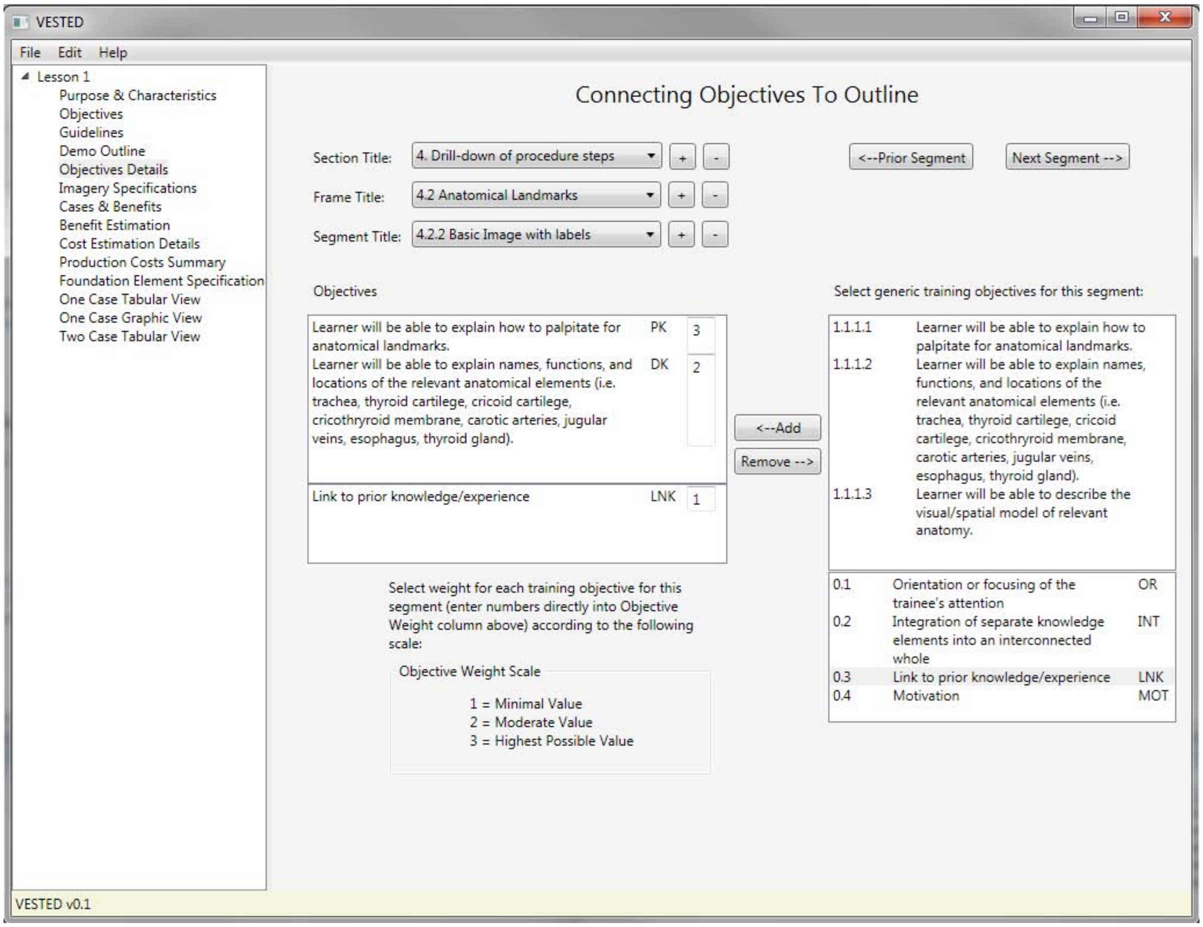


Figure 13. Connecting objectives to outline.

Although we might typically expect the opening section and frames of the demonstration video to address objectives in the areas of orientation, motivation, and linkage to prior relevant knowledge, the user must be allowed to associate any defined objective to each segment. Similarly, we might expect much of the remainder of the video to focus on the various kinds and aspects of relevant target task knowledge – declarative, procedural, conceptual, recognitional, and integrative, but some segments may also serve primarily to address moderating objectives such as motivation or integration with prior knowledge (or any other category of objective). We could identify no good reasons to constrain the author in associating any types of objective to any portions of the storyboard sequence, so complete flexibility is afforded to the user so long as at least one objective is specified for each segment. But multiple category types may be associated with each storyboard segment, recognizing that multiple distinct objectives may be addressed by a single piece of simple or multi-modal content (e.g., with a visual character displaying the performance of a procedure while simultaneously presenting verbal explanation of declarative information, all with a background of motivating visual and auditory imagery). However, no more than a single instantiation of each distinct type of objective category is permitted within a single segment. For example, a segment could have two separate objectives representing different types of knowledge (say one for declarative and one for procedural) but could not have two separate objectives in the same category (say two objectives in procedural

knowledge). This restriction is imposed in order to avoid the problem of creating a formula for aggregating individual benefit estimates within a single data cell. In any situation where the user might want to establish multiple separate objectives in the same category area and associate them with the same segment, it is recommended that the user simply define a new composite objective for which the user can then define the weight and estimated benefits separately from the more elemental objectives.

For each individual association of an objective with a storyboard segment, the user is further required to select an importance 'weight' for that instantiation of that objective according to a simple three-point scale ranging from minimal value (= 1) to highest possible value (= 3). These weights are assigned separately for each segment because of the assumption that different segments may emphasize the same objectives differentially, such as where the same objective may be the central focus of one segment but just a secondary concern in another.

At the conclusion of this step in the VESTED process, the user has characterized the detailed requirements for the training demonstration without regard to how that requirement might be satisfied through an implementation of a training product in some combination of media. In the next step, the user will construct one or more design specifications for candidate alternative plans, or 'cases', for the needed demonstration.

<u>Case construction & benefit estimation</u>. The specifications of objectives and the demonstration outline then serve as the basis for the further development of descriptions of the requirements for video, audio, and text at each finest (segment) level of the storyboard, and these requirements in turn are used to characterize the various media options for each of these elements, including the possible use of legacy materials as well as the construction of new material in any of the pertinent media (see Figure 14). Each complete collection of specifications for a prospective training demonstration is termed as a 'case', with the expectation that typically two or more cases will be constructed to evaluate against one another in order to determine which is likely to be most successful in actual implementation. Our goal in this process is to enable the author to develop the generic storyboard as quickly and efficiently as possible in order to reach an informed decision regarding the use of the available media tools and legacy materials which can then be instantiated into a detailed storyboard and production plan. Before proceeding with further evaluation of costs and benefits of the options, the author is encouraged to identify several distinct storyboard 'cases' (such as one in which all imagery is in VE mode, another that is all photographic video, another that employs exclusively legacy imagery, etc.).

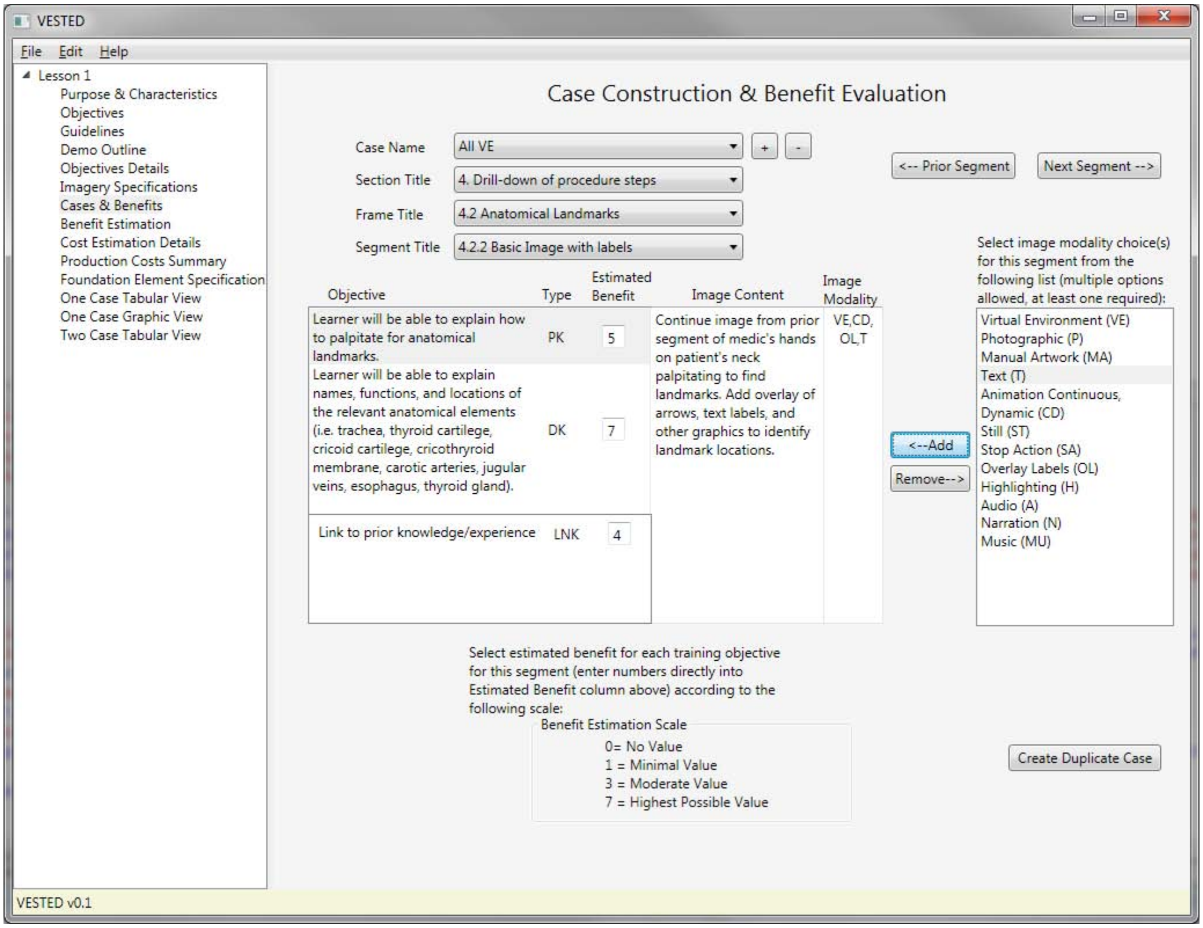


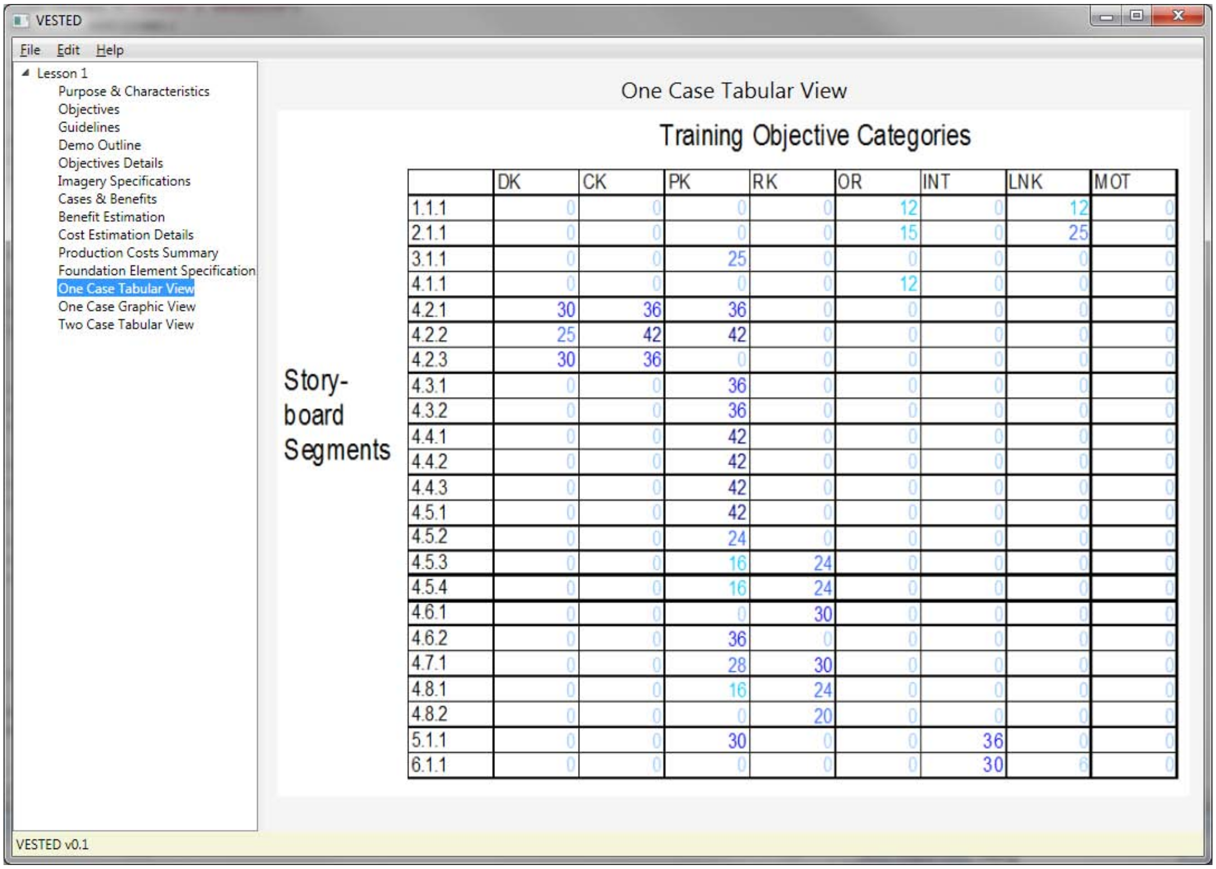
Figure 14. Case construction and benefit estimation in VESTED.

We found that there has been considerable experimental research regarding the training effectiveness of many of the aspects of training demonstration design (e.g., demonstration of typical errors, repetition, perspective, etc.; e.g., see Wouters, Paas & van Merriënboer, 2008 and 2009; Riolo, 1997; White & Hardy, 1995), but very little in the way of definitive, generalizable results. This poses a special challenge for VESTED because the goal of VESTED is to aid the user in making a cost-benefit decision about the best approach for construction of a training demonstration. While the estimation of production costs for the various possible media and legacy material combinations may seem like a manageable challenge, the estimation of training benefits for each case is considered a thornier problem. After careful investigation of both of these aspects of the cost-benefit trade-off, we have concluded that an analytically guided process of subjective estimation is most suitable in both areas.

On the side of training effectiveness benefits, our approach is to ask the user to estimate the benefit on a Likert-type scale for each segment (smallest unit) of the storyboard for each objective that is associated with that segment. Distinct weights were previously specified for each category of training objective (as described above for the “connecting objectives to outline” screen and functionality area). The total estimated benefit for each storyboard segment and

objective category is calculated as the product of the specified weight and the estimated benefit entered by the user.

View benefit evaluation. VESTED enables the user to view weighted benefit estimates across the storyboard timeline with the primary display presenting the weighted benefit for each category of objective (separately) across the timeline of the specified sequence of storyboard segments. It is noteworthy that this presentation no longer differentiates between the arbitrarily many different enabling objectives that were specified in the demonstration requirement, but rather the results for all objectives in an objective category are displayed as a common variable. These estimated measures can also be aggregated across sections, frames, and segments, with user-defined weightings applied to these levels and the results presented by objective category. It is important to be able to view the benefit estimation data for each individual case separately in order to manage and iterate the estimation process, but pairwise comparison of pairs of cases in terms of the differences between benefits for the two cases is expected to be most useful for making selection decisions between cases. The most basic single case display of results is the tabular form of display (see Figure 15) in which the calculated value of “weighted benefit” is presented, possibly with color coding of values in various category ranges of interest. Those same data for the single case can then alternatively be viewed in graphic form (see Figure 16). These data can be useful in aiding the training product developer in insuring that all training objectives are adequately addressed by any give design case. However, in order to make the decision as to which of several design cases to adopt, it is also helpful for the developer to be able to view the complete array of differences in benefit estimates between any two design cases. Such decisions between multiple cases are likely to be frustrated by situations where some segments and objectives produce greater benefits for one case and other cases are superior for other segments and objectives. Thus, by viewing the pattern of differences across all of the estimated benefits between two selected cases, the developer can be expected to judge which would be more preferable in an overall sense. To aid this comparison, VESTED allows the same forms of data presentation used for single cases (Figures 15 and 16) to be applied for the differences in benefit values for any two cases selected by the user (see Figure 17 for the tabular view and Figure 18 for the graphic view). In the different displays, the developer need only observe the sign of each data point to see which of the cases is superior for the segment and objective that it represents.



	DK	CK	PK	RK	OR	INT	LNK	MOT
1.1.1	0	0	0	0	12	0	12	0
2.1.1	0	0	0	0	15	0	25	0
3.1.1	0	0	25	0	0	0	0	0
4.1.1	0	0	0	0	12	0	0	0
4.2.1	30	36	36	0	0	0	0	0
4.2.2	25	42	42	0	0	0	0	0
4.2.3	30	36	0	0	0	0	0	0
4.3.1	0	0	36	0	0	0	0	0
4.3.2	0	0	36	0	0	0	0	0
4.4.1	0	0	42	0	0	0	0	0
4.4.2	0	0	42	0	0	0	0	0
4.4.3	0	0	42	0	0	0	0	0
4.5.1	0	0	42	0	0	0	0	0
4.5.2	0	0	24	0	0	0	0	0
4.5.3	0	0	16	24	0	0	0	0
4.5.4	0	0	16	24	0	0	0	0
4.6.1	0	0	0	30	0	0	0	0
4.6.2	0	0	36	0	0	0	0	0
4.7.1	0	0	28	30	0	0	0	0
4.8.1	0	0	16	24	0	0	0	0
4.8.2	0	0	0	20	0	0	0	0
5.1.1	0	0	30	0	0	36	0	0
6.1.1	0	0	0	0	0	30	6	0

Figure 15. Tabular display of weighted benefit evaluation across storyboard timeline for one case.

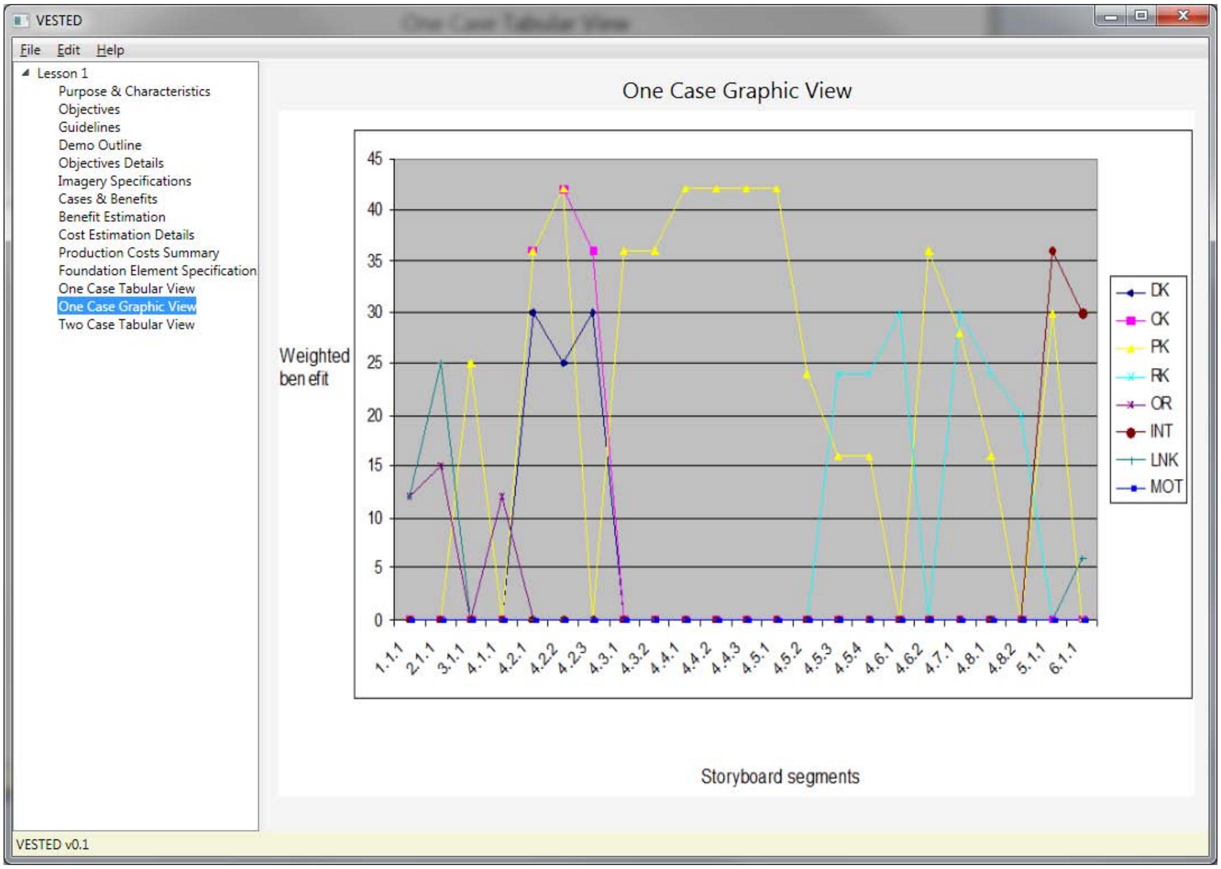
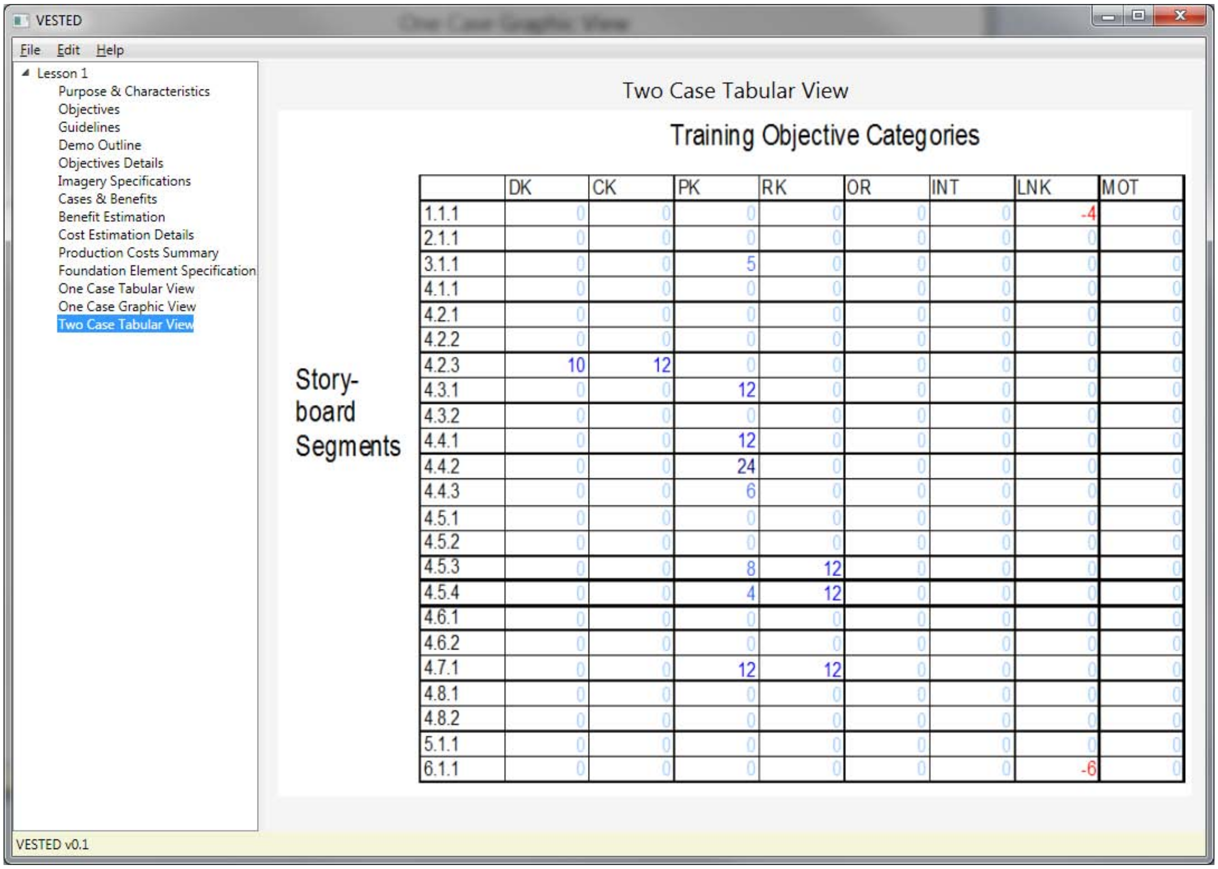


Figure 16. Graphic display of weighted benefit evaluation across storyboard timeline for one case.



	DK	CK	PK	RK	OR	INT	LNK	MOT
1.1.1	0	0	0	0	0	0	-4	0
2.1.1	0	0	0	0	0	0	0	0
3.1.1	0	0	5	0	0	0	0	0
4.1.1	0	0	0	0	0	0	0	0
4.2.1	0	0	0	0	0	0	0	0
4.2.2	0	0	0	0	0	0	0	0
4.2.3	10	12	0	0	0	0	0	0
4.3.1	0	0	12	0	0	0	0	0
4.3.2	0	0	0	0	0	0	0	0
4.4.1	0	0	12	0	0	0	0	0
4.4.2	0	0	24	0	0	0	0	0
4.4.3	0	0	6	0	0	0	0	0
4.5.1	0	0	0	0	0	0	0	0
4.5.2	0	0	0	0	0	0	0	0
4.5.3	0	0	8	12	0	0	0	0
4.5.4	0	0	4	12	0	0	0	0
4.6.1	0	0	0	0	0	0	0	0
4.6.2	0	0	0	0	0	0	0	0
4.7.1	0	0	12	12	0	0	0	0
4.8.1	0	0	0	0	0	0	0	0
4.8.2	0	0	0	0	0	0	0	0
5.1.1	0	0	0	0	0	0	0	0
6.1.1	0	0	0	0	0	0	-6	0

Figure 17. Tabular display of weighted benefit evaluation across storyboard timeline for differences between two cases.

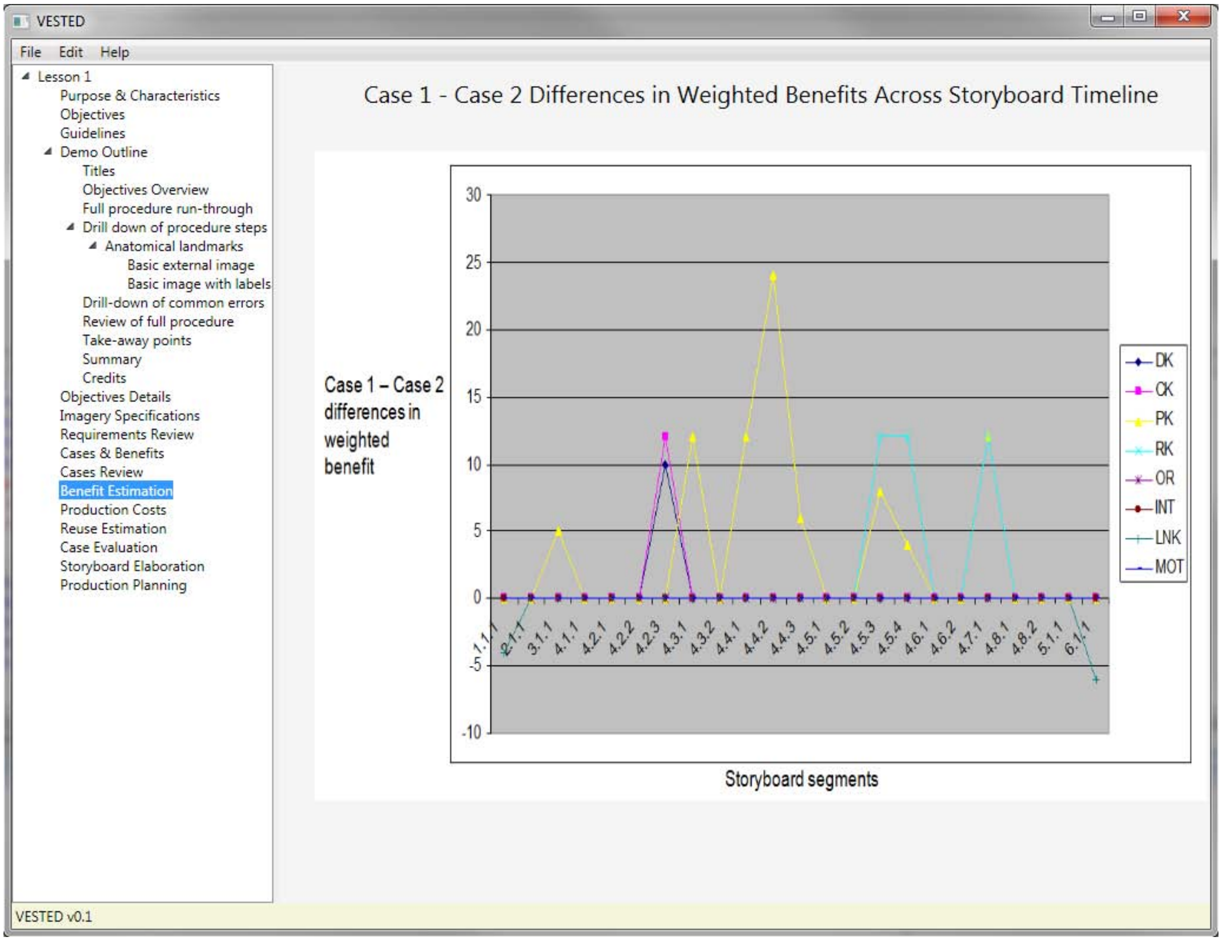


Figure 18. Graphic display of differences in estimated benefits for two cases in VESTED.

<u>Create and view cost estimates</u>. VESTED approaches the estimation of production costs in a somewhat different fashion, recognizing that all production costs cannot typically be apportioned incrementally for each storyboard segment, but rather that there are usually some significant monolithic costs that apply to many or all elements of the storyboard, which VESTED designates as the ‘foundation’ for that storyboard case (see Figure 19).

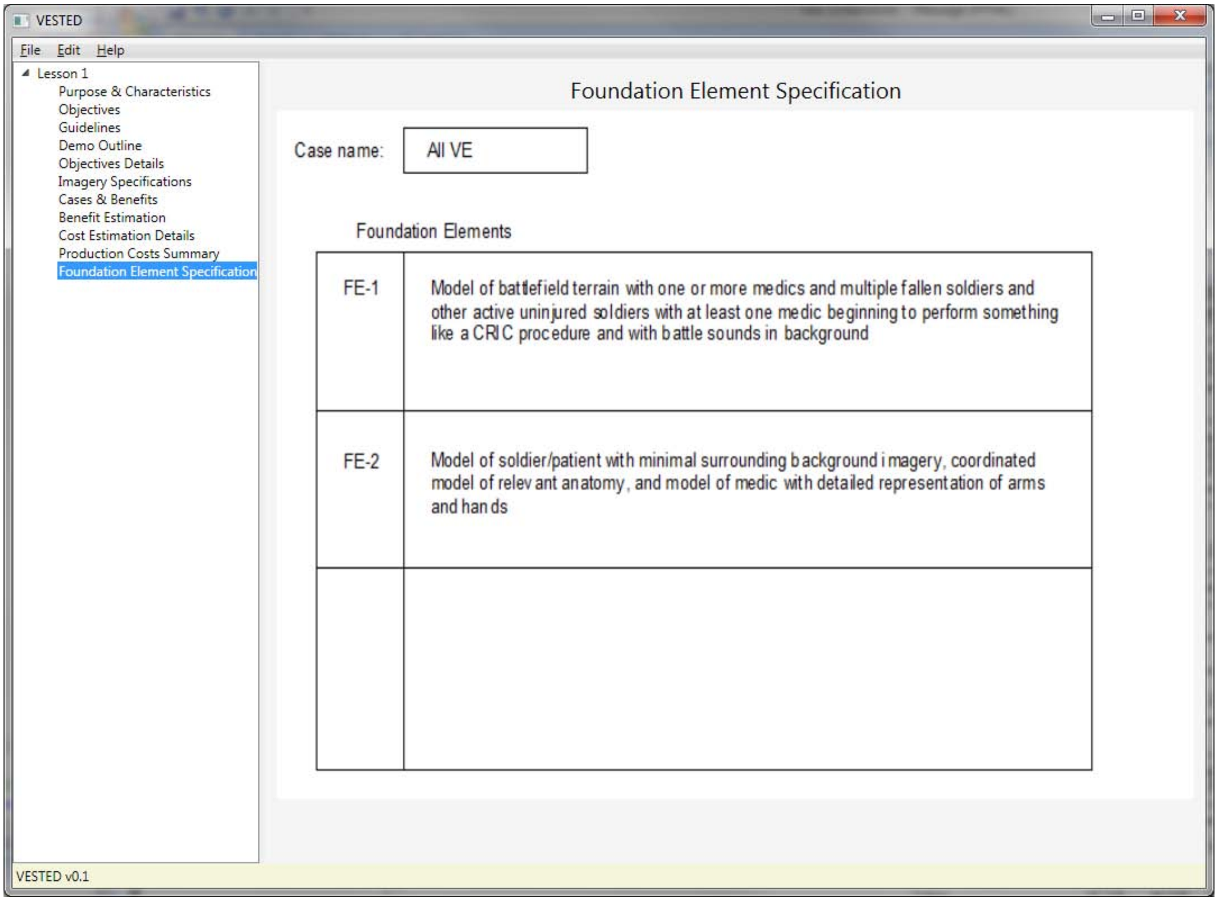


Figure 19. Specification of foundation elements.

For example, there are the costs of buying or renting production equipment, including software packages for various aspects of VE or photographic/video processing and purchase of relevant legacy components that may be commercially available. However, after accounting for all of these costs that cut across segments, the user must estimate the remaining costs that will be required to produce the imagery for each individual segment (see Figure 20).

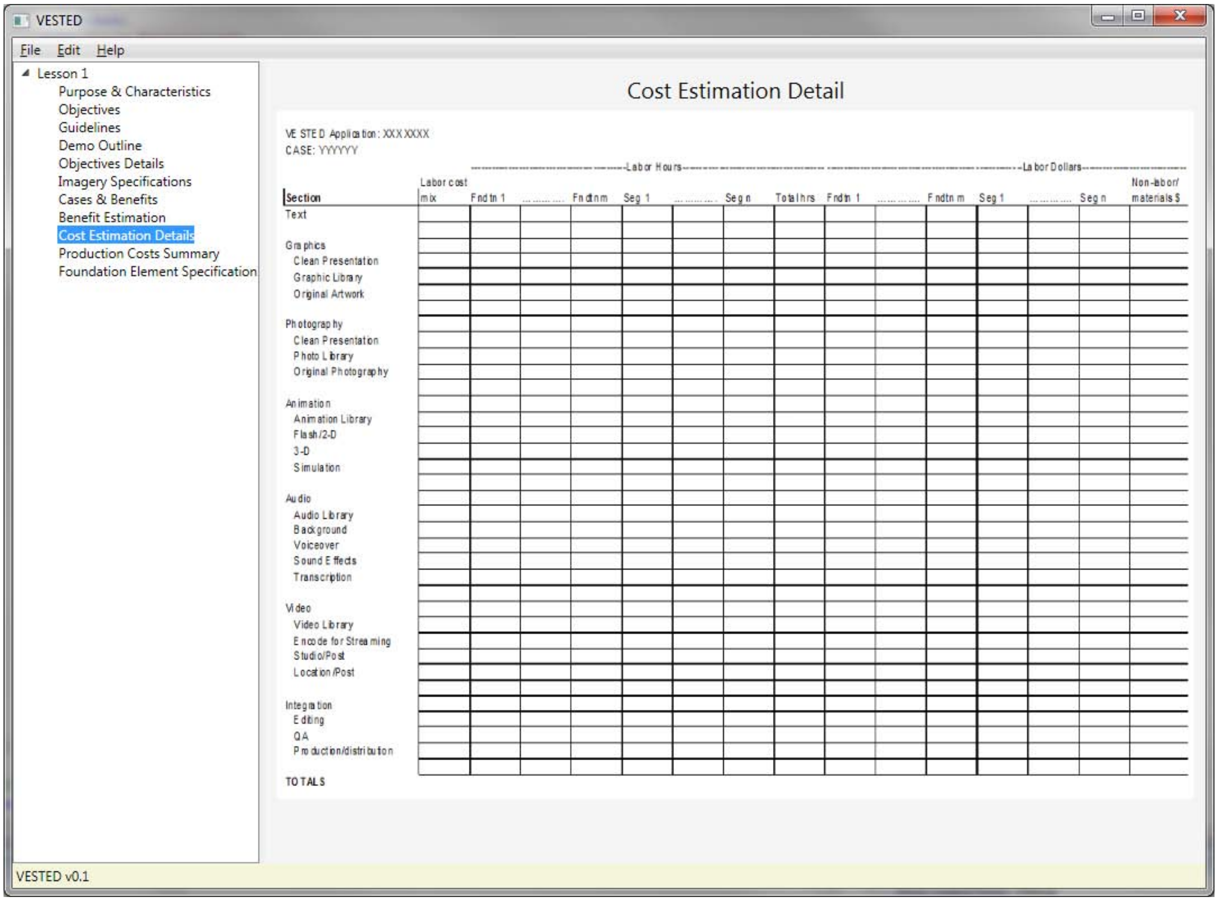
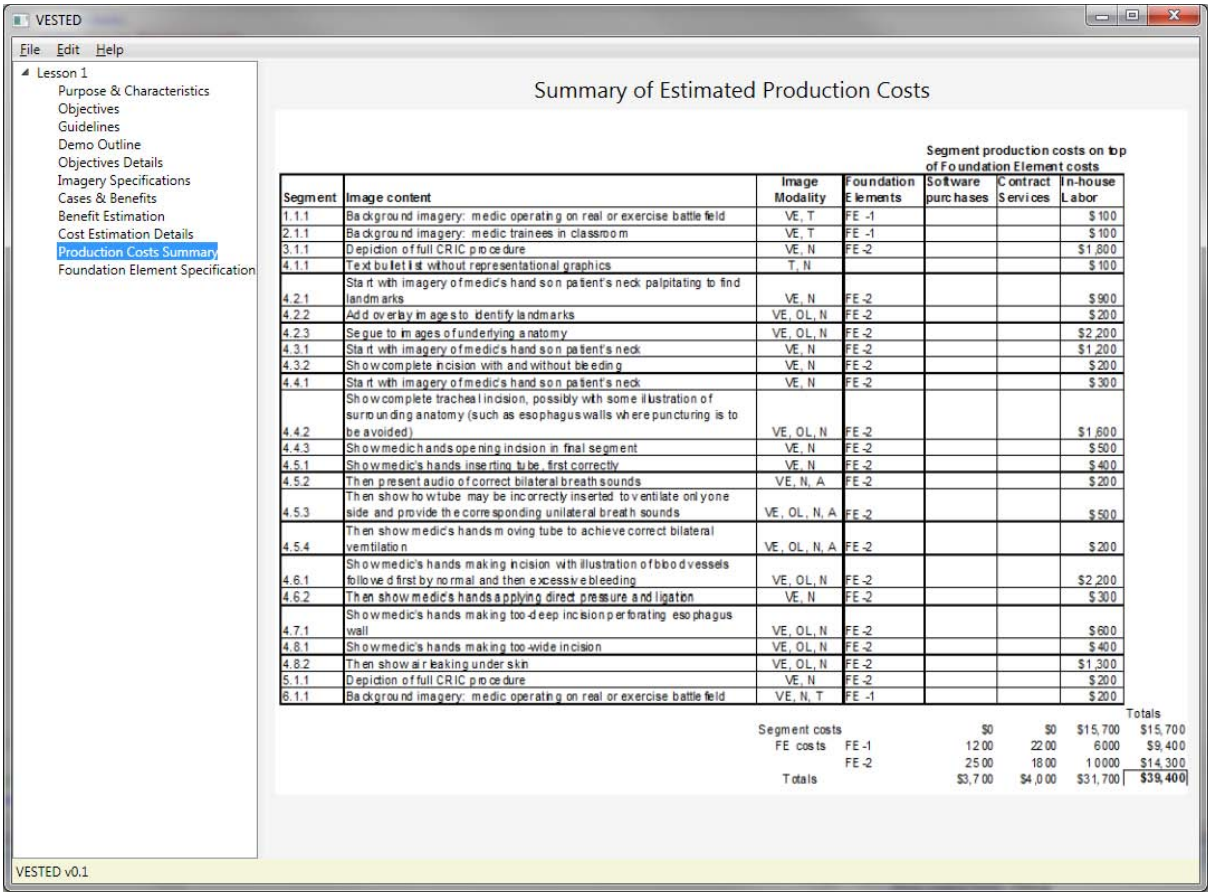


Figure 20. Specification of cost estimation details.

While some of these costs will be well-defined monetary costs for established commercial products, others will probably be in terms of estimated labor hours for in-house or outsourced production work, though estimated hourly labor rates can easily be used to convert the results into aggregated monetary units. A summary of all costs for each case can then be combined and viewed (see Figure 21), initially for each isolated case and then for comparisons of costs across cases.



Segment	Image content	Image Modality	Foundation Elements	Software purchases	Contract Services	In-house Labor	
				Segment production costs on top of Foundation Element costs			
1.1.1	Background imagery: medic operating on real or exercise battle field	VE, T	FE-1			$100	
2.1.1	Background imagery: medic trainees in classroom	VE, T	FE-1			$100	
3.1.1	Depiction of full CRIC procedure	VE, N	FE-2			$1,800	
4.1.1	Text bullet list without representational graphics	T, N				$100	
4.2.1	Start with imagery of medic's hands on patient's neck palpitating to find landmarks	VE, N	FE-2			$900	
4.2.2	Add overlay images to identify landmarks	VE, OL, N	FE-2			$200	
4.2.3	Segue to images of underlying anatomy	VE, OL, N	FE-2			$2,200	
4.3.1	Start with imagery of medic's hands on patient's neck	VE, N	FE-2			$1,200	
4.3.2	Show complete incision with and without bleeding	VE, N	FE-2			$200	
4.4.1	Start with imagery of medic's hands on patient's neck	VE, N	FE-2			$300	
4.4.2	Show complete tracheal incision, possibly with some illustration of surrounding anatomy (such as esophagus walls where puncturing is to be avoided)	VE, OL, N	FE-2			$1,600	
4.4.3	Show medic hands opening incision in final segment	VE, N	FE-2			$500	
4.5.1	Show medic's hands inserting tube, first correctly	VE, N	FE-2			$400	
4.5.2	Then present audio of correct bilateral breath sounds	VE, N, A	FE-2			$200	
4.5.3	Then show how tube may be incorrectly inserted to ventilate only one side and provide the corresponding unilateral breath sounds	VE, OL, N, A	FE-2			$500	
4.5.4	Then show medic's hands moving tube to achieve correct bilateral vemtilation	VE, OL, N, A	FE-2			$200	
4.6.1	Show medic's hands making incision with illustration of blood vessels followed first by normal and then excessive bleeding	VE, OL, N	FE-2			$2,200	
4.6.2	Then show medic's hands applying direct pressure and ligation	VE, N	FE-2			$300	
4.7.1	Show medic's hands making too-deep incision perforating esophagus wall	VE, OL, N	FE-2			$600	
4.8.1	Show medic's hands making too-wide incision	VE, OL, N	FE-2			$400	
4.8.2	Then show air leaking under skin	VE, OL, N	FE-2			$1,300	
5.1.1	Depiction of full CRIC procedure	VE, N	FE-2			$200	
6.1.1	Background imagery: medic operating on real or exercise battle field	VE, N, T	FE-1			$200	
							Totals
		Segment costs		$0	$0	$15,700	$15,700
		FE costs	FE-1	1200	2200	6000	$9,400
			FE-2	2500	1800	10000	$14,300
		Totals		$3,700	$4,000	$31,700	$39,400

Figure 21. Summary of estimated costs.

While the costs can typically be condensed down to a single dollar figure encompassing all cost elements, benefits are necessarily presented more complexly as profiles of the various objective categories across the storyboard timeline. The determination of how to weigh costs against benefits in each situation is necessarily left to the user, though it is expected that there will be occasions where either costs or benefits are very nearly equal between cases of interest so that the decision can be driven by the one criterion that differs across cases.

There is yet another dimension of the cost-benefit consideration that can serve to distinguish VE production efforts from other alternatives – the possible future uses of the planned products. Of course, any training demonstration video can potentially be used in various other training contexts than the initially intended site, and photographic video and manual artwork can be repurposed piecemeal in future productions for all sorts of related applications. However, there is a special transitional value for VE facilities because of their typically expansive adaptability. For example, if we wanted to change some of the details in how to train Army medics in performing the cricoidthyrotomy procedure at some future time, we would probably have to shoot new photographic video in order to adapt a photo/video product, whereas it would probably be possible with relatively minor effort and cost to modify the behaviors of the pertinent avatars to exhibit the revised procedure. While it may be difficult to anticipate future requirements where such adaptation may be beneficial, and it will always be important to

appropriately discount the uncertainties associated with those speculations, such opportunities for future reuse are expected to constitute significant decision criteria in some cases.

Thus, the separation of foundation costs from storyboard-segment costs is based on our expectation of the potential reuse of portions of an initial demonstration product to address subsequent training requirements. A key expectation in this area is the likelihood that it would be much less costly to adapt an initial VE product for subsequent similar training applications than would be the case for a conventionally produced video demonstration. Although there is no current compelling empirical evidence to support this expectation, there is also no good reason to reject it either. This expectation of a VE reuse advantage is based on the idea that there is a collection of foundational or intermediary products for VE projects (i.e., virtual models for objects, characters, dynamics, etc.) that can be reused much more extensively and readily in the VE case than for any analogous foundational elements for other media, especially relative to the medium of conventional video production with live actors. Accordingly, VESTED defines the foundation for a production case as all of the efforts, materials, and related costs that are independent of, and usually precedent to, the creation of the individual segment products. Thus, for conventional video production, the foundation would include access to all of the necessary cameras, microphones, recording and processing equipment, sets, etc., while the corresponding foundation for VE would involve construction of the basic VE models for human characters, tools and other objects that are central to the intended training, and background environmental elements. The VESTED user is asked first to define the complete collection of foundation requirements (see Figure 19) for each production case of interest (recognizing that most cases will not be ‘pure’ representations in just one production medium but will rather be implemented as hybrids of multiple media).

Following the specification of the foundation requirements, the user estimates the cost of creating all of the foundation elements in all relevant media production categories, and then the similar estimates for the costs of producing the required segment products for each storyboard segment, assuming that all foundation elements are available to support efforts for each segment. This complete collection of cost estimation requirements is illustrated in the spreadsheet format of Figure 20 which is envisioned for eventual implementation in VESTED as a simpler, more streamlined sequence of multiple interface screens.

In order to estimate the costs of projected future reuses of an initial product case, the user is asked to make separate estimates of the percentage of modifications that will be required to the foundation portions and the segment-specific portions of each case being considered, along with a separate estimate of the likely lag time until the production of the new product. These estimates may be made for several distinct subsequent production efforts being considered (e.g., later adaptations of an initial demonstration to some closely related training domains, or periodic updates to the initial demonstration to reflect changing technology). In order to calculate expected costs and potential benefits of one case over another, the VESTED tool can calculate basic costs for the new products as the estimated costs of the original components multiplied by the estimated modification percentages and then discounted and/or inflated according to the lag time before the product is planned (see Figure 22).

		Initial Product		---------------- Subsequent Prod A ---------			-------------	---------------- Subsequent Prod A ---------			-------------
VESTED Application: XXXXXXX		All fndtn costs	All segmer costs	Lag time to new product	Percent mod to fndtns	Percent mod to segments	Estimated Cost	Lag time to new product	Percent mod to fndtns	Percent mod to segments	Estimated Cost
Case #	Comment										
1	All VE										
2	VE + photo intro										
3	All photo video										
4	Slides + legacy video										

Figure 22. Estimation of projected reuse costs.

VESTED Software Design

The VESTED system design includes three specific components, each mapped to one of the demonstration processes described in the VESTED conop including: a demonstration specification tool which enables a demonstration author to define instructional storyboards utilizing an objective-based guideline-driven process, a video generation tool which utilizes a variety of game-based engines to facilitate the instantiation of the storyboards in the form of raw videos, and a video mixing tool which enables a demonstration author to mix the raw videos, using the VESTED guidelines, and thereby produce instructionally-meaningful demonstration videos. The VESTED approach relies on a concept whereby a range of video-generation tools (i.e., "game-engines") can be utilized within the overall VESTED solution depending on the specific demonstration requirements identified by the author. The overall vision for the VESTED functional architecture is depicted in Figure 23.

VESTED Software Concept

The central piece of the VESTED system is the authoring toolset which provides the main portal through which the demonstration author identifies training objectives, creates storyboards, defines storyboard alternatives (i.e., cases), and performs cost-analyses of multiple cases. The authoring and analysis tool is designed to function as a standard desktop application. The primary function of the VESTED system is to provide the author with an organizing tool to aid them in making the decisions about where and how to use the VE medium and all of the relevant other authoring tools. The basic concept of VESTED is to offer a tool to aid the author in articulating the objectives, requirements, and constraints for a planned training demonstration, then to guide them through the development of one or several storyboard 'cases' that would satisfy those conditions, and finally to structure the cost-benefit decision of selecting a preferred case and elaborating its specification into a detailed production plan. Specifically, the VESTED authoring tool provides authoring across four functional areas including:

- purpose/characteristics/guidelines,
- training requirements definition,
- training benefits analysis,
- training product cost analysis.

The VESTED demonstration specification tool was constructed as a stand-alone desktop application and was written in C# with Microsoft's .NET framework. We leveraged both the Windows Presentation Foundation (WPF) and Language Integrated Query (LINQ) components within the .NET framework.

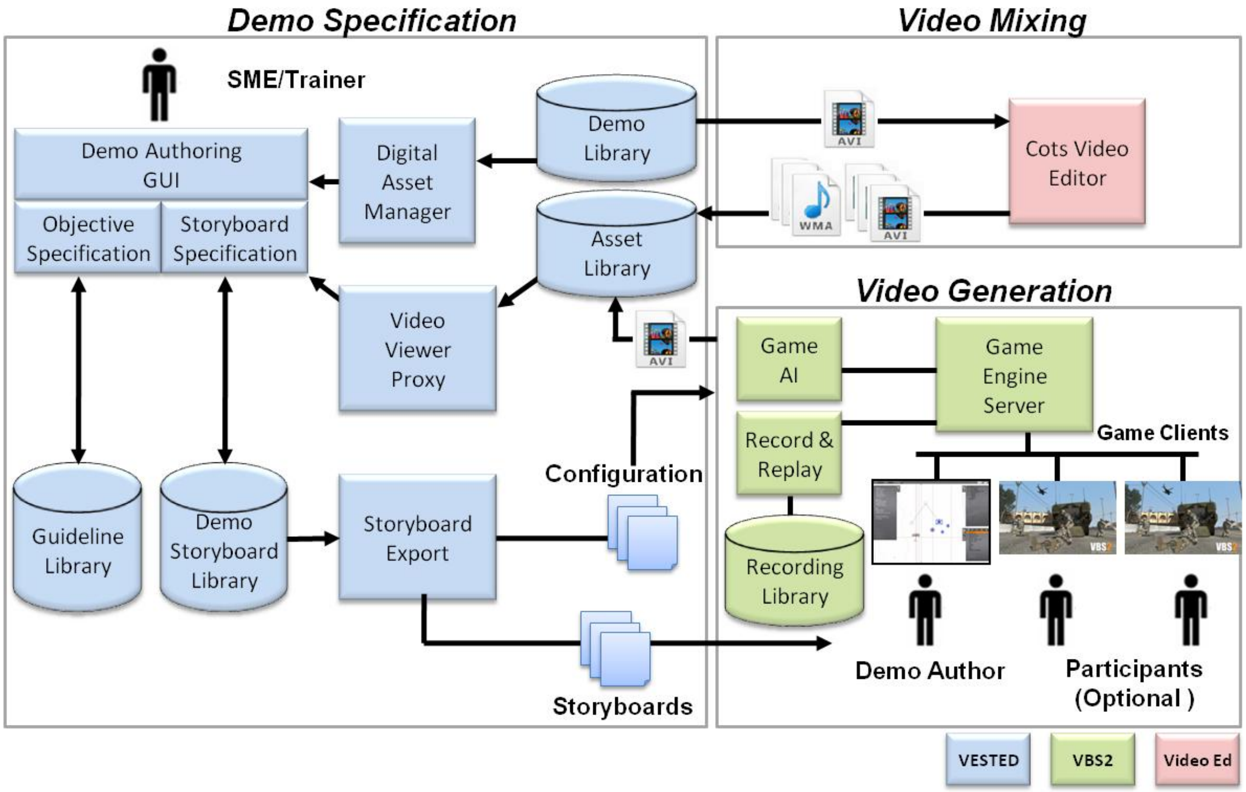


Figure 23. VESTED functional system design vision.

The full VESTED vision would utilize a commercial game engine system to provide a virtual-environment for creating 3D representations of authored demonstrations (as opposed to the standard tabular storyboard entry). Basic placement and editing of the scenario entities would be accomplished via the existing editing capabilities of the game system. For any given engine, there may be additional components which would need to be built to provide additional capabilities to that particular game engine (e.g., entity behaviors). A number of criteria are important in the examination of commercially available game engines to support VESTED requirements, such as malleability, usability of graphical user interfaces, capabilities/limitations, and deployability.

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Appendix A: Bibliography in Categories Relevant to VESTED

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